A KNOWLEDGE MANAGEMENT FRAMEWORK FOR REDUCING THE COST OF POOR QUALITY ON CONSTRUCTION PROJECTS

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ABSTRACT

Knowledge management (KM) implementation strategies on construction projects can reap benefits such as improved performance and continuous improvement yet many projects are characterised by inefficiencies, repetition of mistakes and lack of lessons learnt. Poor skills, design changes, errors and omissions contribute to the internal failure cost element of the Cost of Poor Quality (COPQ) while the resultant effect of client dissatisfaction contributes to the external failure cost. COPQ is prevalent regardless of project type and has been found to be over 10% of total project cost in certain cases. While the need to reduce COPQ is definite, it is uncertain what impact KM has in its reduction. The aims of the research therefore are twofold (i) to investigate the impact of KM in reducing COPQ on construction projects (ii) to develop a KM framework for reducing COPQ on construction projects.

A mixed method approach was adopted for the research with an exploratory sequential research design utilising both qualitative and quantitative inquiries to address the research aims. Semi-structured interviews and questionnaire survey were selected as the method for qualitative and quantitative data collection respectively. The interviews were conducted with 25 industry experts involved in KM strategies for large construction organisations across UK to obtain data, based on their experiences and expertise on projects, which were then analysed using content analysis. The output from the analysis yielded variables and working hypotheses which were tested through the questionnaire survey. Further data were obtained from 114 survey respondents who have been mostly involved in KM initiatives for large construction organisations across UK. The data was analysed using descriptive statistics.

From the interpretation of the entire qualitative and quantitative data, it was found that KM can be complex and difficult to manage within organisations and on projects. Although KM was perceived to have positive impact in reducing COPQ, organisations did not, and could not quantify COPQ neither could they measure the extent of the impact of KM on COPQ. Causal links were found between COPQ elements i.e. errors and omissions, design changes and poor skills, contrary to the theoretical suggestion of being mutually exclusive. It was found that KM currently has not been optimised to reduce COPQ due to a number of barriers. Optimising KM to reduce COPQ therefore involves overcoming the barriers as follows: develop performance metrics to assess the impact of KM on COPQ on projects; appoint knowledge champions to facilitate KM activities to reduce COPQ; adopt a positive organisational culture towards KM; allocate adequate time and budget for KM activities on projects; select procurement strategies that support and facilitate KM.

A KM framework for reducing COPQ on construction projects was developed as an output of the research and evaluated by industry practitioners. It can be concluded that the optimisation of KM can significantly reduce COPQ. A key recommendation for industry practitioners therefore is to adopt a holistic approach to quantifying COPQ and assessing the impact of KM in reducing COPQ such as the one presented in this research. The research contributes to the body of knowledge in the area of cost reduction, quality improvements and knowledge management on projects.

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CHAPTER 1

INTRODUCTION TO RESEARCH

This chapter discusses the research problem, the rationale for the research and the knowledge gap the research aims to fill. It presents the research questions, states the research aims and discusses the research objectives. It identifies the novelty of the research and discusses the research benefits. It discusses the contributions of the research output to the body of knowledge. The chapter finally presents the structure of the thesis.

1.1 STATEMENT OF THE RESEARCH PROBLEM

Knowledge management (KM) is invaluable to the construction industry due to its potential in integrating knowledge across personal, organisational, project and industry boundaries. KM implementation strategies can reap benefits such as improved project performance and continuous improvement yet many projects are plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to additional project costs (Al-Ghassani et al., 2004; Egbu, 2005; Suresh et al., 2008; Carrillo et al., 2013; Ren et al., 2013; Garstenauer et al., 2014). A major area of focus is on the cost attached to the unnecessary effort of re-doing processes or activities incorrectly implemented the first time often referred to as the cost of poor quality (COPQ). This constitutes the cost of errors and omissions, cost of design changes, cost of poor skills and the consequential costs associated with client dissatisfaction (Feigenbaum, 1991; Juran and Godfrey, 1999; Josephson and Hammarlund, 1999; Love and Edwards 2005; Rosenfeld, 2009; Urbancová and Vnoučková, 2015).

Studies have found COPQ to be prevalent on projects regardless of project type or size. Burati et al. (1992) found quality deviations in nine engineering projects to be an average of 12.4% of the contract value. Abdul-Rahman (1995) found non-conformance costs to be 5% of contract value on a highway project. Nylen (1996) found quality failures to be 10% of contract value on a railway project. Love and Li (2000) found rework costs in residential and industrial buildings to be 3.15% and 2.4% of contract value respectively. Researchers have attempted to find the mean value of costs. Love (2002) found the mean direct and indirect rework costs on 161 construction projects to be 6.4% and 5.6% of the original contract value respectively.

Hwang (2009) obtained data from 359 construction projects and found direct rework costs alone to be 5% of total construction costs. Love et al. (2010) found the mean rework costs to be 10% of the contract value in civil infrastructure projects. COPQ is endemic and is a major contributory factor to client dissatisfaction, reduced profitability of the supply chain and reduced reputation of the construction industry as a whole (Egan 1998, 2002; Wolstenholme, 2009). As a result there is critical need to formulate strategies for reducing COPQ particularly in a post-recession economy in which the construction industry is still adversely affected. Moreover the need for cost efficiency has become a major driver and a source of competitive advantage for construction organisations.

1.2 RATIONALE FOR THE RESEARCH

The rationale or the logical basis for undertaking the research was driven by the research problem i.e. the endemic COPQ on construction projects. While COPQ may be regarded as a quality management problem in which case initiatives such as Total Quality Management (TQM), Six Sigma and Lean principles are applicable (De Feo and Barnard,2005; Pyzdek and Keller, 2009; Koskela et al., 2013), the study takes a different approach by exploring the link between KM and COPQ. While not suggesting that quality management initiatives may be replaceable with KM, the study focuses on KM aspects such as the repetition of mistakes and lack of lessons learnt which may lead to COPQ issues. The rationale therefore is based on the need to reduce COPQ on projects and the need to harness and integrate knowledge across personal, organisation, project and industry boundaries.

1.2.1 The need to reduce the cost of poor quality on construction projects

COPQ can be sub-divided into internal failure costs and external failure costs. Internal failure costs are incurred when rectifying errors or defects before a product is handed over to the client, while external failure costs are incurred due to errors or defects detected after the product has been handed over (Feigenbaum, 1991; Juran and Godfrey, 1999; Defeo and Juran, 2010). Internal failure costs can be referred to as the cost of non-conformities and inefficient processes with cost indicator measured in terms of plant and material usage, labour and time. External failure costs consist of the cost associated with client dissatisfaction which includes the cost of penalties and the costs of potential loss of opportunities for future revenue. Unlike the manufacturing industry which has made significant progress in improving efficiency and reducing costs, the construction industry still lags behind in this area. This has been indicated in several industry reports over the years (e.g. Latham, 1994; Egan, 1998, Wolstenholme, 2009; Cabinet Office, 2011; BIS, 2013). Indeed the reports have continually highlighted the construction industry's under-achievement, low profitability of the supply chain and client dissatisfaction with products and services provided. . One of the 'drivers' which needed to be in place to secure improvement in the construction process and end-product was identified as 'a quality driven agenda' (Egan, 1998). Evidence, however suggests that the construction industry in its current state is yet to achieve the quality agenda (Wolstenholme, 2009; BIS, 2013). Both governmental and customer demands for enhanced product quality and lower product and production cost in construction creates a need to investigate and identify opportunities for improving quality, reducing costs, thereby reducing customer dissatisfaction with the goods or services received. The rationale for this research therefore originates from the need to reduce the endemic COPQ problem on construction projects.

1.2.2 The need to harness and integrate knowledge across boundaries

Construction contributes £90 billion gross value added to the UK economy (nearly 7% of the total GDP), comprises over 280,000 businesses and accounts for 3 million jobs; this is equivalent to about 10% of total UK employment (HM Government, 2013). Despite its enormous size, the construction industry is overwhelmingly made up of small, local firms with fewer than 20 employees, and a few larger firms employing thousands of people. For a regional project, the subcontract size may be even smaller, with examples of projects where 70% of sub-contracts were below £10,000. Because of the very large number of small firms, the industry is often characterised as un-concentrated. This is clear evidence of the fragmentation of the industry and a real demonstration of the challenge of building integrated supply chains with a close focus on the end product and customer value. There are limited numbers of general contractors who are capable of managing very large projects, whereas there are large numbers of small subcontractors. The large contractors however engage the small and medium size contractors on large construction projects. According to EC Harris (2013), in a typical large building project (i.e. £20 - £25 million range), the main contractor may be directly managing around 70 sub-contracts of which a large proportion are small organisations (£50,000 or less)

KM is therefore invaluable to the construction industry as it is deemed critical for construction organisations to harness and integrate knowledge in order to improve efficiency and increase profitability. It is particularly important due to the arguably unique characteristics of projects such as the complicated nature of operations, multitude of occupations, professions and organisations, temporary team members, heavy reliance on experience, one-off nature of projects, tight schedules and limited budgets (Zin and Egbu, 2010; Zarzu and Scarlat, 2015). The nature in which the construction industry is organised means that, efficiency in project delivery is less than expected, resulting in dissatisfied clients and low profitability for construction organisations. There is an awareness of the need to strategically manage employee-owned tacit knowledge within construction organisations (Carrillo and Chinowsky, 2006; Anand et al., 2010) and the need for knowledge integration across personal, organisational and project boundaries (Ruan et al. 2012). This suggests that KM is becoming increasingly important in construction.

The construction industry however remains criticised for being poor at learning, often ‘reinventing the wheel’, repeating mistakes and wasting resources (Robertson, 2002; Grimaldi and Rippa, 2011). Specialist and technical knowledge is often lost from one project to the next, stifling an organisation’s ability to retain and re-use knowledge (Egbu and Botterill, 2000; Liu et al., 2013). The project-based, fragmented and unstable nature of the industry has led to significant knowledge loss compared with other industries (Graham and Thomas 2008). The need to attract, retain and develop more of the right people to improve industry capability has also been recognised (Wolstenholme 2009). The rationale in this case therefore is rooted in the need to harness and integrate knowledge across boundaries.

1.3 KNOWLEDGE GAPS

The knowledge gaps identified for the research are threefold; the first relates to the body of work on COPQ, the second relates to the body of work on KM, while the third relates to the integration of KM with COPQ.

1.3.1 The body of work on the cost of poor quality

While attempts have been made by authors to quantify COPQ, none of them has adopted a holistic approach in its quantification. Instead, previous studies have focused on the constituent aspects of COPQ, such as quality failures (e.g. Nylen, 1996), non-conformance costs (e.g. Abdul-Rahman, 1995), deviation costs (e.g. Cnuddle, 1991; Burati et al., 1992), direct and indirect rework costs (e.g. Love et al., 2002; Hwang, 2009), design and construction related change orders (e.g. Cox et al., 1999; Love et al., 2010). While all these aspects relate to COPQ, none of the authors adopted an integrated approach in quantifying all the aspects. The aspects include errors and omissions, design changes, and poor skills, which lead to rework, delays and wastage, which are then quantified in terms of plant, material, labour, time, and penalty costs. There is therefore no unified methodology or consistent approach to quantifying COPQ neither is there a unified terminology in describing the aspects of COPQ. This creates difficulty in comparing 'like-for-like' performance from project to project, which is a crucial step to formulating strategies for reducing COPQ. This research intends to bridge the knowledge gap by integrating all the aspects and presenting a holistic model to quantifying COPQ.

1.3.2 The body of work on knowledge management

Much of the research and many of the publications in the area of KM take an organisational perspective and relatively little attention has been given to the impact of KM exploitation on construction projects. These studies typically focus on ways of managing the knowledge resources and capabilities of an organisation through the use of KM processes and tools with the overall aim of gaining competitive advantage over potential competitors (e.g. Newell et al., 2009; Skyrme, 2011; Garstenauer and Olson, 2014). In an ideal construction project environment however, the aim of the supply chain organisations should not be to gain competitive advantage against one another but to work collaboratively to deliver successful projects that bring the best products and services to clients (e.g. Smyth, 2010; BIS, 2013). In this case KM should advance beyond organisational level through the utilisation of a more robust approach in developing a push-pull strategy for knowledge integration across personal, organisational, project and industry interfaces in order to retain existing knowledge and to create new knowledge. This key aspect is missing in the existing body of work on KM; this research therefore intends to bridge the gap in this area.

1.3.3 Integrating knowledge management and the cost of poor quality

While KM and COPQ may be viewed as two distinct areas in practice, evidence suggests a link between the two. However none of the existing body of work has examined the interconnectedness of KM and COPQ. Furthermore no research has been found to date that has investigated the impact of KM on COPQ neither have there been any framework or tools developed to measure the impact. This study therefore intends to bridge the identified gap in this significant research area.

1.4 RESEARCH QUESTIONS

A key methodological step in undertaking research is to identify and specify the research questions to be addressed. The research questions are based on the research problem and the knowledge gap the research intends to bridge. The main research questions for this study are stated as follows:

(1) What are the contributory factors to the cost of poor quality on construction projects in practice?

(2) What is the impact of knowledge management in reducing the cost of poor quality based on the identified contributory factors?

(3) How can knowledge management be optimised to reduce the cost of poor quality on construction projects?

1.5 RESEARCH AIMS AND OBJECTIVES

The aims of the research are stated as follows:

(1) To investigate the impact of knowledge management in reducing the cost of poor quality on construction projects

(2) To develop a knowledge management framework for reducing the cost of poor quality on construction projects.

In order to address the aims, the following research objectives were identified:

(1) To critically review existing literature in the area of KM from both general and construction industry perspectives in order to explore, identify and document the key concepts, processes, tools, KM drivers, enablers, benefits, barriers and issues relating to KM and the possible link to COPQ

(2) To critically review existing literature in the area of quality management with a specific focus on COPQ in construction, in order to explore, identify and document the key concepts of quality, the causes of poor quality, the costs associated with poor quality, the quality management initiatives for reducing COPQ, the issues relating to COPQ in construction and the possible link to KM.

(3) To develop a conceptual framework on the impact of KM in reducing COPQ on construction projects based on the output from literature review, in order to synthesise KM and COPQ concepts and to guide the research in the collection, interpretation and explanation of data.

(4) To collect qualitative and quantitative data from construction organisations across UK in order to investigate the impact of KM in reducing COPQ on construction projects in practice.

(5) To analyse the data from objective 4, comparing the theoretical constructs from objectives 1 – 3 with the analysed data in order to interpret and document the findings, modify the conceptual framework and present a final KM framework for reducing COPQ on construction projects.

(6) To evaluate the proposed framework using selected construction practitioners involved in knowledge management activities.

(7) To summarise the findings, draw final conclusions and recommendations on the impact of KM in reducing COPQ on construction projects.

1.6 NOVELTY OF THE RESEARCH

Novelty relates to the quality of research being new or original. The novelty of this research is closely linked to the knowledge gaps identified as a result of an extensive search and critical review of existing literature relevant to the research. In this research, the novelty is based on two aspects: (1) synthesis of previous body of work (2) new approach to addressing an endemic research problem.

1.6.1 Synthesis of previous body of work

As identified in the research gap, previous studies lack a unified methodology in calculating COPQ on construction projects. While authors have only attempted to calculate aspects of COPQ in parts, this study presents a holistic approach to quantifying it. This is achieved by synthesising aspects of previous studies to create a robust and unified model for quantifying COPQ regardless of project type and size.

Previous studies on KM have focused on ways of managing the knowledge resources and capabilities of an organisation through the use of KM processes and tools with relatively little attention given to the impact of KM exploitation on construction projects. However this research goes further from the organisational context by synthesising the ‘knowledge conversion’ model with the project supply chain model to create knowledge interfaces across personal, organisational, project and industry boundaries with measurable impact.

1.6.2 New approach to addressing an endemic research problem

Despite the quality management initiatives such as Total Quality Management (TQM), Six Sigma and Lean principles, COPQ is still endemic on construction projects. While COPQ may be regarded as a quality management problem, this study takes a different approach by examining the interconnectedness between KM and COPQ. The key reasons for this approach are based on the on-going issues in the construction industry such as lack of lessons learnt, repetition of mistakes, loss of vital project knowledge, poor knowledge retention and re-use.

The research therefore aims to investigate the impact of KM in reducing COPQ on construction projects. The output of the research is a KM framework for reducing COPQ. No previous studies have covered this area therefore contributing to the novelty of this research.

1.7 RELEVANCE OF THE RESEARCH

There is tendency for research to become obsolete over the course of the research project for a number of reasons e.g. changes to the research status quo due to new findings, or due to the research problem being solved already elsewhere. This research however has been found to be valid and relevant to date as COPQ remains endemic. Recent industry reports (e.g. BIS, 2013; HM Government, 2013) have re-iterated the need to reduce the cost of construction across all types of projects. It can therefore not be over-stated that the industry needs improvement in this area which the research presents a solution and offers real practical application for reducing COPQ on construction projects. Continuous updates on literature review also ensure that there is no duplication of work with other ongoing research.

1.8 BENEFICIARIES OF THE RESEARCH

The beneficiaries of this research are diverse and they include:

- Organisations in the construction supply chain particularly the main contractors since they execute the practical aspects projects and engage several other sub-contractors. Depending on the contract type, the main contractor organisation typically forms the core of the supply chain, interfacing with the client organisation, consultants, and suppliers. The output from the research will improve efficiency on projects and reduce costs thereby increasing profitability. The architecture or design organisations also benefit from the research by understanding the cost implications of design changes and the impact KM can have in reducing design changes.

- Senior management from construction organisations will benefit from the output of the study particularly those involved in project management, knowledge management, quality management and cost management of organisations.
- Policy makers in the construction industry will benefit from being able to track construction project cost reductions and to obtain data for future industry reports.

1.9 CONTRIBUTIONS TO THE BODY OF KNOWLEDGE

- The output from the research contributes to the body of knowledge in the area of KM and quality management particularly in understanding the impact of KM in reducing COPQ on construction projects. Previous studies have not covered this area therefore this study provides a new valuable insight for industry practitioners and academics.
- The research presents a new definition of ‘quality’ in the construction context which adds to the body of knowledge in quality management. It also presents a new definition of KM in construction which contributes to KM body of knowledge.
- The research presents a KM model for harnessing and integrating knowledge across personal, organisational, project and industry

boundaries which adds to the body of knowledge both for academics and industry practitioners.

- The research presents a holistic approach to quantifying COPQ by integrating elements of previous studies in areas such as rework, delays, and wastage on projects. The new COPQ model is applicable for use in the industry and for studies in academia.
- The research presents a KM framework for reducing COPQ on construction projects which has never before been presented in academia and industry. This framework is different from the KM model aforementioned.
- The research provides new insight into how organisations can improve project efficiency, reduce repetition of mistakes and reduce 're-inventing the wheel'.
- Output from the study contributes to industry knowledge in the area of best practice and continuous improvement on projects.
- Different aspects of the research work have been disseminated at various academic seminars, workshops and conferences which have stimulated positive debates and created new knowledge in the areas of KM and COPQ.
- Aspects of the research work have led to academic publications while the main outputs are currently in the process of being published e.g.

  Olayinka R., Suresh, S., and Chinyio, E. (2012) Reducing the Cost of Poor Quality through Knowledge Management. Proceedings of COBRA, RICS Foundation 11 – 13 September, Arizona State University, Arizona USA

Olayinka R., Suresh, S., Chinyio, E., and Proverbs, D. (2011) A critique on the Definitions of ‘Quality’ in the Construction Industry’ Proceedings of the 10th International Post Graduate Research Conference (IPGRC), 14th -15th September. Pp 217-283

1.10 STRUCTURE OF THE THESIS

The structure of the thesis is explained by the methodological process of the research shown in Figure 1.1. The thesis contains 9 chapters which are arranged in a sequential and logical manner commencing with the Introduction in this Chapter 1 and ending with Conclusion in Chapter 9.

Chapter 2 examines the existing body of work on knowledge management. It critically reviews past and current literature on the conceptualisations of knowledge and knowledge management. It explores knowledge management processes and supporting tools. It examines strategic aspects such as the key drivers, enablers, barriers and benefits of knowledge management. It also examines knowledge management initiatives and applications within the construction industry. It finally identifies the issues relating to knowledge management within the construction project management context.

Chapter 3 examines the existing body of work on quality management with a specific focus on the cost of poor quality on construction projects. It discusses the conceptualisations of quality including key definitions and applications. The chapter reviews and presents findings from three case studies obtained from a secondary source which deal with construction stakeholders’ influence on the definition of quality on construction projects.

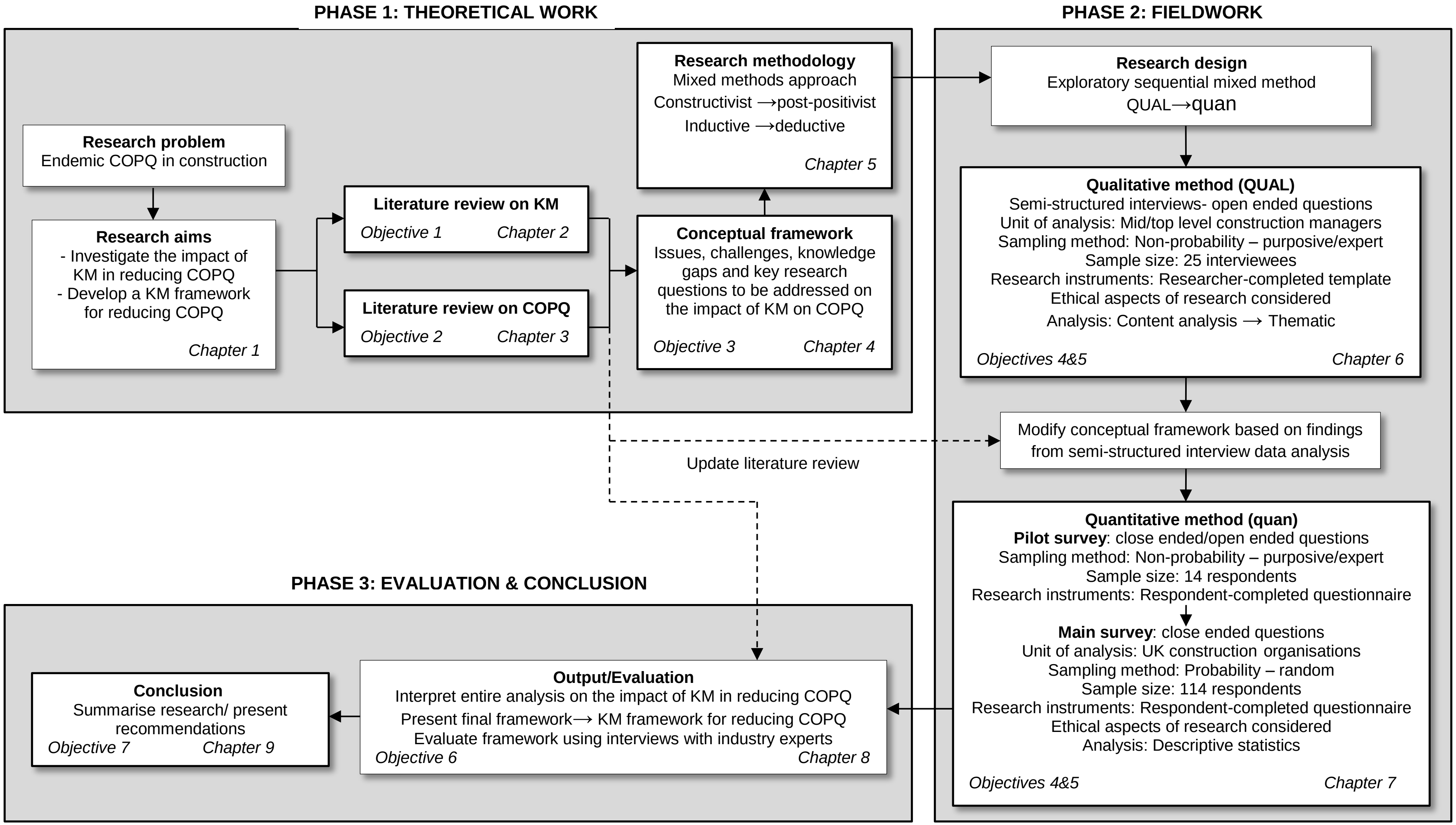


Figure 1. 1: Structure of the thesis and the methodological process of the research

It explores the causes of poor quality and examines the resultant costs associated with poor quality on construction projects. It quantifies the cost of poor quality based on the work of previous authors. The chapter explores quality management initiatives and tool used by organisations in reducing costs of poor quality. It finally discusses the issues relating to COPQ in construction project management.

Chapter 4 synthesises the bodies of work on knowledge management and the cost of poor quality. It examines the links between knowledge management and the prevalent cost of poor quality on construction projects. It identifies the issues, challenges, knowledge gaps and key research questions on the impact of knowledge management in reducing the cost of poor quality. It presents the key research questions together with a matrix showing the areas of inquiry. It distinguishes between a theoretical framework and a conceptual framework. It also presents an initial conceptual framework for the study which is subject to modifications at later stages of the study.

Chapter 5 discusses the methodology used for the research. It provides an overview of the methodological process comprising of literature review, conceptual framework, the research approach and the validation of framework. It examines different research approaches and their underlying philosophical assumptions. It explores different research designs or strategies of inquiry available for research including methods for data collection and analysis. It discusses the selection and justification of the research approach, research design and research methods for this study. The chapter also discusses the sampling strategies and ethical issues considered for the research.

Chapter 6 discusses the results from the qualitative study on the impact of knowledge management on the cost of poor quality. It presents the profile of the interviewees involved in the study. It discusses the findings on the contributory factors to the cost of poor quality in practice which includes the cost of errors and omissions, cost of design changes and the cost of poor skills. The chapter discusses the findings on the impact of knowledge management on these costs. It presents and discusses the findings on the optimisation of knowledge management to reduce the cost of poor quality on construction projects. It discusses the implications of the findings and presents the hypotheses to be tested in a subsequent quantitative study. The chapter also presents a modified conceptual framework incorporating the hypotheses and draws conclusions on the overall qualitative study.

Chapter 7 presents the results and analysis of the quantitative data obtained through questionnaire survey. It discusses the findings on the impact of KM processes for reducing COPQ on construction projects, the effectiveness of KM tools in reducing COPQ, the barriers to KM in reducing COPQ, the benefits of reducing COPQ through KM optimisation, and the measurement of the impact of KM on COPQ. The chapter also discusses the implications of the findings and conclusions.

Chapter 8 presents an interpretation of the entire data i.e. qualitative and quantitative. It connects all aspects of the research including the main research questions, findings and conclusions from both qualitative and quantitative inquiries. It discusses the overall impact of knowledge management on errors and omissions, design changes and poor skills. It presents the knowledge management framework for reducing the cost of poor quality on construction projects. It also discusses the evaluation of the framework.

Chapter 9 presents a reflective review of the methodological process of the research. It re-states the research aims and objectives. It discusses how the research objectives were achieved. It reviews the research methods and research outputs and their links to the research objectives. It presents the key findings of the research from both theoretical work and fieldwork. It also presents the recommendations, limitations of the research and direction for further work and future studies.

CHAPTER 2

A REVIEW OF LITERATURE ON KNOWLEDGE MANAGEMENT

This chapter examines the existing body of work on knowledge management. It critically reviews past and current literature on the conceptualisations of knowledge and knowledge management. It explores knowledge management processes and supporting tools. It examines strategic aspects such as the key drivers, enablers, barriers and benefits of knowledge management. It also examines knowledge management initiatives and applications within the construction industry. It finally identifies the issues relating to knowledge management within the construction project management context.

2.1 CONCEPTUALISATIONS OF KNOWLEDGE

This section addresses the following areas of inquiry relevant to the conceptualisations of knowledge e.g. what is knowledge? How is knowledge conceptualised? How is knowledge distinguished from data, information and wisdom? What are the types of knowledge? Which types of knowledge are relevant to knowledge management?

2.1.1 Definition of knowledge

It is fundamental to examine the basic foundations of KM in order to set the background for the study and to establish a working definition of knowledge itself. Epistemology, the branch of philosophy dealing with knowledge attempts to answer the basic question ‘what is knowledge?’ Epistemology aims at; (1) ‘understanding ourselves and the environment that surrounds us’; (2) searching for judgemental criteria that distinguish truth from falsehood. (Goldman, 1986; Russell, 1948) Epistemology therefore is concerned with the process of knowing or how to justify true knowledge as a result, scientific methods have conceptually become an integral part of many epistemologies.

Efforts to define knowledge can be traced back to the days of Greek philosophy. Plato (427-347 BC) provided three definitions; (1) knowledge is perception (2) knowledge is true judgement (3) knowledge is justified true belief (Annas 2003). Aristotle (384-322 BC) on the other hand put more emphasis on logical and empirical methods for gathering knowledge but still accepts the view that such knowledge is concerned with necessary and universal principles. Subsequent philosophers who explored the concept of knowledge were divided between Plato's and Aristotle's viewpoints. Consequently, two philosophical perspectives of knowledge emerged namely the idealist and empiricist perspectives.

The idealist perspective is based on Plato's viewpoints that knowledge is a state of being, while the empiricist perspective is based on Aristotle's viewpoint that knowledge is doing (Jashapara, 2003; 2011). The idealist perspective starts with perception and then true judgment develops and this translates into true judgment together with an account. On the other hand, the empiricist perspective starts with appearance, works through puzzles and then comes back to appearance. Idealistic postulations of knowledge are existentialist while empiricist postulations are pragmatic (Oluipke, 2007).

Table 2. 1 Philosophical perspectives of Knowledge

(Source: Hegel and Gray, 1997)

Idealist (being)	**Year**	**Empiricist (doing)**	**Year**
Plato	427-347 BC	Aristotle	384-322 BC
Descartes	1596-1650	Locke	1632-1704
Kant	1724-1804	Hume	1711-1976
Hegel	1770-1831	Pierce	1839-1914
Husserl	1859-1938	Dewey	1859-1952
Heidegger	1889-1976	Wittgenstein	1889-1951
Sartre	1905-1980		

The philosophical concept of knowledge is very broad and often complex and will not be discussed in this study but it is worth mentioning the two philosophical viewpoints that have emerged. Early philosophical work also has great influence on the logic of recent literature and the concept of knowledge and its management in the present day. For instance, Nonaka and Takeuchi (1995) defined knowledge as a dynamic human process of justifying personal belief toward the 'truth'. This reflects the earlier discussed philosophical view of Plato who defined knowledge as 'justified true belief'.

Scarborough (1996) defined knowledge as a canonical body of fact and rational laws which is similar to Aristotle's rational and empirical view point. According to Merriam Webster (1996), knowledge is 'the fact or condition of knowing something with familiarity gained through experience or association'. Familiarity with someone or something can include information, descriptions, facts, or skills acquired through experience or education. Davenport and Prusak (1998) further defined knowledge as a fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. Gardner (1995) summarised the definitions of knowledge as; (1) ‘know what’ - knowing which information is needed; (2) ‘know why’ - knowing why information is needed; (3) ‘know how’ - knowing how information must be processed; (4) ‘know where’ - knowing where information can be found to achieve a specific result; and (5) ‘know when’ - knowing when which information is needed.

The definition of knowledge has also varied from one era to another (Jashapara, 2011). The world has undergone various eras such as the antiquity era, agriculture era, industrial era, information era and now the knowledge era. During the antiquity era, knowledge was associated with manners and custom guides (Bennett, 2003; Jashapara, 2011), however during the agricultural era knowledge related to agriculture and the work force (Wiig, 1997). In the industrial era, knowledge was focused on product leadership, operational excellence, finance, production statistics, metrics for reporting and standards (Skyrme, 2000). As time progressed into the information era, knowledge focused on leadership, management, organisational theory and capitalism (Bennett, 2003). The knowledge era is associated with harnessing intangible assets, creating value, innovation statistics, and metrics for managing (Skyrme, 2000).

From the plethora of definitions to date it would appear that there is no final coherent definition of knowledge, however definitions can be classified into traditional (e.g. Plato and Aristotle) and contemporary (e.g. Davenport and Prusak, 1998; Skyrme, 2000). Traditional epistemology can only be of limited use to knowledge management since it focuses on the origins and justification of personal knowledge rather than the pragmatics of knowledge use. The contemporary definitions are more relevant to knowledge management as they focus on the pragmatics of knowledge use and on the notion of knowledge as a practical tool for framing experiences, sharing insights and assisting with practical tasks. Although knowledge management entails the justification knowledge, more importantly it deals with the understanding of the uses of knowledge in order to effectively deal with tasks that involve knowledge-based activity. This study therefore focuses on the contemporary definitions, concepts and applications.

2.1.2 Distinguishing between data, information, knowledge and wisdom

A further means of defining knowledge in the contemporary context is to clarify what knowledge is not. Attempts to distinguish between data, information, knowledge and wisdom (often used interchangeably), gear towards the understanding knowledge (Webb, 1998). Studies have described the differences among Data, Information, Knowledge and Wisdom (DIKW) in terms of a richness hierarchy which considers wisdom as the richest and deepest of the four (Zarzu and Scarlat, 2015). Data consist of facts, observations, or perceptions. Data may be devoid of context, meaning, or intent but can easily be captured, stored, and communicated via electronic or other media. Information involves the manipulation of raw data to obtain a more meaningful indication of trends or patterns in the data. Knowledge is distinguished from data and information in that knowledge refers to information that enables action and decisions, or information with a direction. Knowledge is the appropriate collection of information, such that its intent is to be useful. Knowledge is built from data, which is first processed into information. Wisdom brings together experience, cognitive abilities, and affect for good decisions to be made (Ackoff, 1989; Sternberg, 1990; Blumentritt and Johnston, 1999; Becerra-Fernandez et al., 2004; Becerra-Fernandez and Leidner, 2008; Nurnberger, and Wenzel, 2011; Zarzu and Scarlat, 2015).

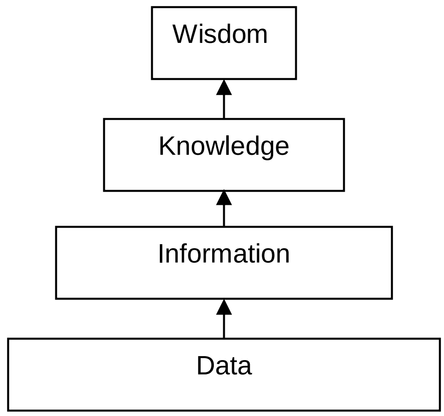


Figure 2. 1: The DIKW hierarchy

Although the DIKW hierarchy has been widely adopted within the knowledge management circle, researchers have critiqued and proposed alternative models. Clarke (2005) for example included ‘understanding’ to the DIKW as an interpolative and probabilistic process which is cognitive and analytical (see Figure 2.2). It was described as the process by which new knowledge can be synthesised from the previously held knowledge. The difference between understanding and knowledge is the difference between ‘learning’ and ‘memorising’. People who have understanding could undertake useful actions because they can synthesize new knowledge, or in some cases, at least new information, from what is previously known and understood. Understanding therefore can build upon currently held information, knowledge and understanding itself. Another example is the ‘DIKIW’ model proposed by Liew (2013) which included ‘intelligence’ as the unit of analysis in the DIKW hierarchy stating that intelligence has inseparable relationships with knowledge and wisdom (see Figure 2.3). Examining the various concepts in their entirety is beyond the scope of this study however it was important to utilise the DIKW hierarchy as a means of gaining more insight into what knowledge is and what it is not. This lays the background to knowledge management.

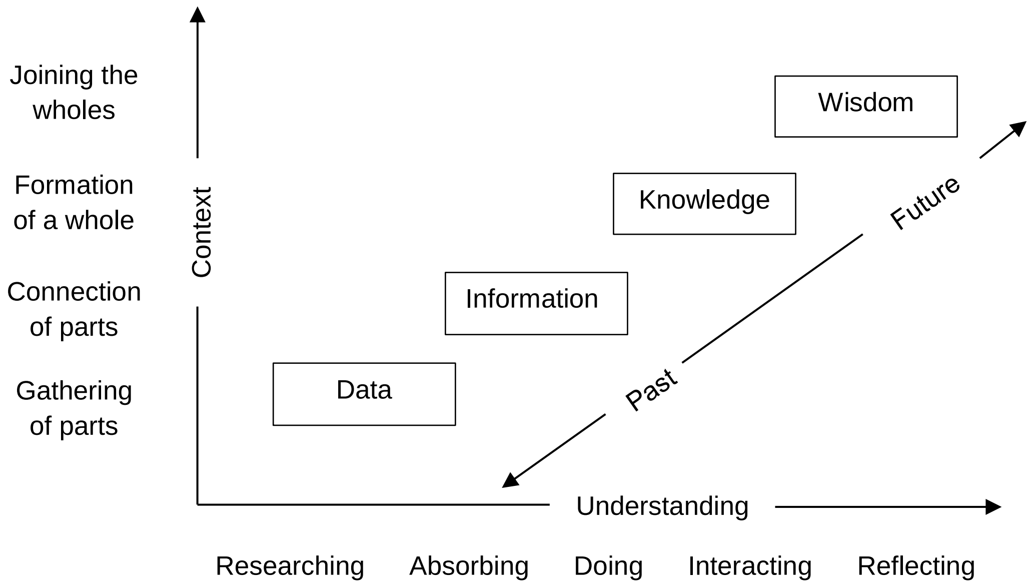


Figure 2. 2: Alternative DIKW model
(Adapted from Clarke, 2005)

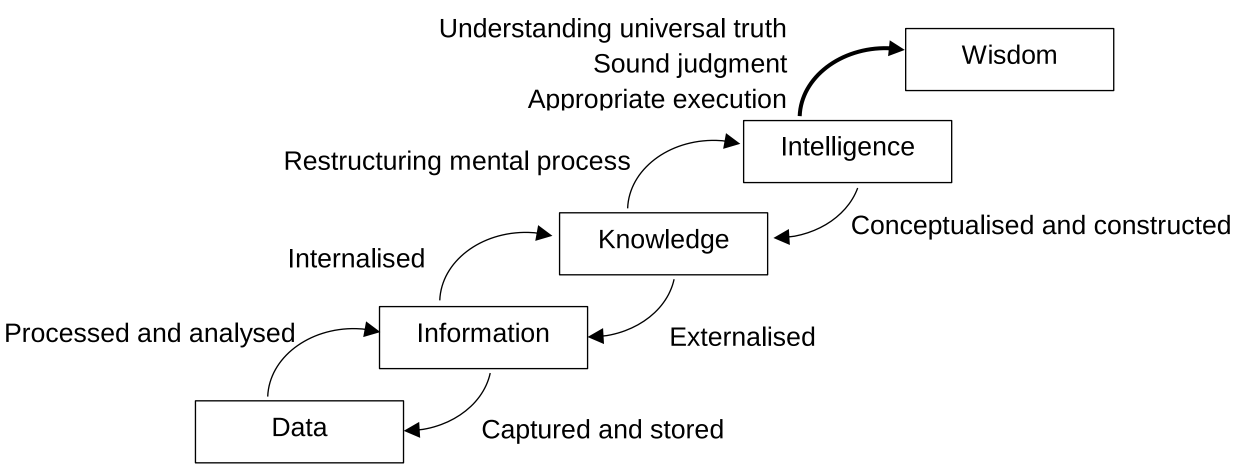


Figure 2. 3: The ‘DIKIW’ model
(Source: Liew, 2013)

2.1.3 Types of knowledge

There are two main types and several sub-types of knowledge identified from previous studies. The main types are explicit knowledge and tacit. Explicit knowledge is knowledge that can be expressed in formal and systematic language and shared in the form of data, scientific formula, specifications, and manuals and among a wide range of knowers. Tacit knowledge however is subjective and experience based, not visible thus not easily expressed, understood or measured, hard to encode and communicate (Polanyi, 1966; Nonaka, 1994; Nonaka et al. 2000). There are two dimensions to tacit knowledge; technical, and cognitive. Technical dimension encompasses informal skills, crafts, expertise or ‘know-how’ acquired through years of experience but difficult to articulate in a formal way. Cognitive dimension consists of schema, mental models, beliefs and perceptions so ingrained that they are taken for granted (Nonaka and Takeuchi, 1995).

The sub-types include procedural knowledge, declarative knowledge, causal knowledge, conditional knowledge and relational knowledge (see Table 2.2). Procedural knowledge or ‘know-how’ is a process whereby knowledge about how to perform a task accumulates with experience over time (Argote and Epple, 1990; Swart et al., 2014). Prior experience often dictates future knowledge possibilities thereby rendering the process a cumulative and path-dependent phenomenon. Once created such knowledge may reside in individuals, organisational routines and processes (Argote, 1995; Jain and Moreno, 2015). Declarative knowledge or ‘know what’ results from knowledge generated through interactions, for example between producers and users of their products. Such knowledge are usually documented (Karnoe, 1993).

Causal knowledge or 'know why' involves controlled experimentation and simulation to understand the principles and underlying theories underlying the functioning of a system. Accumulation of knowledge is cumulative within the confines of an overall paradigm (Laudan, 1984) Prior knowledge is essential to assimilate new knowledge (Cohen and Levinthal, 1990). Conditional knowledge refers to knowing when and why to use declarative and procedural knowledge. Relational knowledge or 'know with' is the knowledge that resides intangibly with individuals through relations with others.

Table 2. 2: Summary of knowledge types, sub-types and characteristics

	Description
Knowledge types	
Explicit knowledge	• Knowledge that can be expressed in formal and systematic language
Tacit knowledge	• Subjective and experience based, not easily expressed, understood or measured, hard to encode and communicate
Knowledge sub-types	
Procedural knowledge	• 'Know-how'- process whereby knowledge about how to perform a task accumulates with experience over time
Declarative knowledge	• 'Know-what'- results from knowledge generated through interactions, for example between producers and users of their products. Such knowledge are usually documented
Causal knowledge	• 'Know-why'- involves controlled experimentation and simulation to understand the principles and underlying theories underlying the functioning of a system.
Conditional knowledge	• Refers to knowing when and why to use declarative and procedural knowledge
Relational knowledge	• 'Know-with'- knowledge that resides intangibly with individuals through relations with others
Knowledge characteristics	
Knowledge is embedded	• Resides within routines. It relates to the relationships between roles, technologies, formal procedures within a complex system
Knowledge is embodied	• Action oriented and consists of contextual practices over time
Knowledge is embrained	• Dependent on conceptual skills and cognitive abilities, and is considered to be practical, high-level knowledge, where objectives are met through perpetual recognition and revamping
Knowledge is encoded	• Information that is conveyed in signs and symbols (e.g. books, manuals, data bases) and de-contextualised into codes of practice.
Knowledge is encultured	• Shared understandings through socialisation and acculturation

Studies have explored the characteristics of knowledge and found that: knowledge is embedded in practice; knowledge is embodied; knowledge is embrained; knowledge is encoded; and knowledge is encultured. Embedded knowledge is explicit and resides within routines. It relates to the relationships between roles, technologies, formal procedures and emergent routines within a complex system (Blackler 1995). Embodied knowledge is action oriented and consists of contextual practices i.e. 'knowledge by doing' (Tsoukas, 1996). Embrained knowledge is dependent on conceptual skills and cognitive abilities, and is considered to be practical, high-level knowledge, where objectives are met through perpetual recognition and revamping.

Tacit knowledge may also be embrained, even though it is mainly subconscious. Encoded knowledge is information that is conveyed in signs and symbols (e.g. books, manuals, data bases) and de-contextualised into codes of practice. Rather than being a specific type of knowledge, it deals more with the transmission, storage and interrogation of knowledge (Lam, 2000). Encultured knowledge is the process of achieving shared understandings through socialisation and acculturation (Zins, 2007; Urbancová and Vnoučková, 2015). A summary of knowledge types, knowledge characteristics and description are shown in Table 2.2. Lam (2000) explained that four of the types of knowledge, excluding encultured knowledge which was not mentioned, arose from the explicit-tacit and individual-collective dimensions of knowledge. This is shown in the Figure 2.4. There exists a plethora of other knowledge types and sub-types, most of which can be classified under tacit or explicit knowledge.

	Individual	Collective
Explicit	Embrained knowledge	Encoded knowledge
Tacit	Embodied knowledge	Embedded knowledge

Figure 2. 4: Relationships between knowledge types and characteristics
(Source: Lam, 2000)

For example Grunstein and Barthes (1996) presented ‘intangible’ and ‘tangible’ knowledge dichotomy while Kimble et al. (2001) presented ‘soft’ and ‘hard’ knowledge being two parts of a duality. However both can be classified under tacit and explicit knowledge respectively. Other knowledge types include: product, process and people (Robinson et al., 2001); domain, organisational, project (Whetherill et al., 2002); factual, catalogue, cultural (Heron, 1996); company, corporate, technical, management (Grenstein and Barthes, 1996); personal, organisational (Cheung, 2006), all of which possess tacit and explicit knowledge elements

2.2 CONCEPTUALISATIONS OF KNOWLEDGE MANAGEMENT

This section addresses the following areas of inquiry relevant to the conceptualisations of knowledge management e.g. What is knowledge management? How is knowledge management conceptualised? What are knowledge management processes and tools? How does knowledge management fit into organisational strategy?

2.2.1 Operationalising the definition of knowledge management

There exists an in-exhaustive list of definitions of KM, several of which were generated in the last two decades, the period in which KM gained enormous popularity among researchers and practitioners. The multitude of definitions can appear daunting and confusing (Jashapara 2011), conflicting and overlapping (Anan and Singh 2011). Yet it has been argued that the cause can be linked to the multidisciplinary nature of KM having its roots in a number of other distinct disciplines such as philosophy, human resource management, information systems, linguistics, and business (Dalkir 2005, Schwartz 2006). As a result there is a tendency of each definition toward the root discipline it originated from.

According to Davenport and Prusack (1998), ‘knowledge management draws from existing resources that an organisation may already have in place, good information systems management, organisational change management and human resource management practices'. This definition has its roots in information systems and human resource management. Newell et al. (2009) defined KM from a business perspective as '…improving the ways in which firms facing highly turbulent environments can mobilise their knowledge base in order to ensure continuous innovation'. Similarly, Skyrme (2011) defined KM as ‘the explicit and systematic management of vital knowledge and its associated processes of creation, organisation, diffusion, use and exploitation in pursuit of business objectives.

Apart from the multidisciplinary perspective, it is often debated whether KM is a tool, a process or strategy. As a tool, Bounfour (2003) defined KM as a set of procedures, infrastructures, technical and managerial tools, designed towards creating, sharing and leveraging information and knowledge within and around organisation. As a process, Fischer (2001) defined KM as a cyclic process involving, creation, integration and dissemination of knowledge. Similarly, Skyrme (2002) presented KM as a continuous cyclic process comprising of knowledge identification, collection, classification, storage, sharing, access, usage, and new knowledge creation. As a strategy, O'Dell and Grayson (1997) defined KM as a conscious strategy of getting the right knowledge to the right people at the right time, and helping people to share and put the information into action in ways that strive to improve organisational performance. Despite the differences and variations in definitions of knowledge management, commonalities were found and can be summarised as the operational definition as follows:

‘Knowledge management entails harnessing and integrating knowledge across boundaries through the adoption of processes and supporting tools for the strategic benefit of an organisation’

Harnessing and integrating knowledge involve the interactions between the two types of knowledge namely tacit and explicit. The interactions between the knowledge types have been conceptualised by Nonaka and Takeuchi (1995) who proposed a model for their facilitation. The model is known as the ‘SECI’ (Socialisation, Externalisation, Combination, Internalisation) and is widely adopted in knowledge management circles. Having explored the definitions of knowledge management, the four commonalities were found and are stated as follows:

- Harnessing and integrating knowledge (conceptualised by the SECI model)
- Adopting a knowledge management process

- Utilising knowledge management tools
- Aligning knowledge management with organisational strategy

The study therefore critically examines the each of the four commonalities in order to develop a framework for application in the construction management context.

2.2.2 Harnessing and integrating knowledge

An organisation harnesses and integrates knowledge through the interactions between explicit knowledge and tacit knowledge. The interactions between the two types are referred to as knowledge conversion which results in the creation of new knowledge. There are four modes of knowledge conversion namely Socialisation (tacit to tacit conversion), Externalisation (tacit to explicit), Combination (Explicit to explicit) and Internalisation (Explicit to tacit), hence the acronym ‘SECI’. The SECI model resulted from the work of Nonaka and Takeuchi (1995). This is briefly discussed as follows:

Socialisation is the process of converting new tacit knowledge through shared experiences. Since tacit knowledge is difficult to formalise and often time- and space-specific, tacit knowledge can be acquired only through shared experience, such as spending time together or living in the same environment. Socialisation typically occurs in a traditional apprenticeship, where apprentices learn the tacit knowledge needed in their craft through hands-on experience, rather than from written manuals or textbooks. Socialisation may also occur in informal social meetings outside of the workplace, where tacit knowledge such as world views, mental models and mutual trust can be created and shared. Socialisation also occurs beyond organisational boundaries. Firms often acquire and take advantage of the tacit knowledge embedded in customers or suppliers by interacting with them.

Externalisation is the process of articulating tacit knowledge into explicit knowledge. When tacit knowledge is made explicit, knowledge is crystallised, thus allowing it to be shared by others, and it becomes the basis of new knowledge. Concept creation in new product development is an example of this conversion process. Another example is a quality control circle, which allows employees to make improvements on the manufacturing process by articulating the tacit knowledge accumulated on the shop floor over years on the job. The successful conversion of tacit knowledge into explicit knowledge depends on the sequential use of metaphor, analogy and model.

Combination is the process of converting explicit knowledge into more complex and systematic sets of explicit knowledge. Explicit knowledge is collected from inside or outside the organisation and then combined, edited or processed to form new knowledge. The new explicit knowledge is then disseminated among the members of the organisation. Creative use of computerised communication networks and large-scale databases can facilitate this mode of knowledge conversion. When the comptroller of a company collects information from throughout the organisation and puts it together in a context to make a financial report, that report is new knowledge in the sense that it synthesises knowledge from many different sources in one context. The combination mode of knowledge conversion can also include the ‘breakdown’ of concepts. Breaking down a concept such as a corporate vision into operationalised business or product concepts also creates systemic, explicit knowledge.

Internalisation is the process of embodying explicit knowledge into tacit knowledge. Through internalisation, explicit knowledge created is shared throughout an organisation and converted into tacit knowledge by individuals. Internalisation is closely related to ‘learning by doing'. Explicit knowledge, such as the product concepts or the manufacturing procedures, has to be actualised through action and practice. For example, training programmes can help trainees to understand an organisation and themselves. By reading documents or manuals about their jobs and the organisation, and by reflecting upon them, trainees can internalise the explicit knowledge written in such documents to enrich their tacit knowledge base.

Explicit knowledge can be also embodied through simulations or experiments that trigger learning by doing. When knowledge is internalised to become part of individuals' tacit knowledge bases in the form of shared mental models or technical ‘know-how’, it becomes a valuable asset. This tacit knowledge accumulated at the individual level can then set off a new spiral of knowledge creation when it is shared with others through socialisation. Knowledge created through each of the four modes of knowledge conversion interacts in the spiral of knowledge creation. Figure 2.5 shows the four modes of knowledge conversion and the evolving spiral movement of knowledge through the SECI process. In the spiral of knowledge creation, the interaction between tacit and explicit knowledge is amplified through the four modes of knowledge conversion. The spiral becomes larger in scale as it moves up through the ontological levels. Knowledge created through the SECI process can trigger a new spiral of knowledge creation, expanding horizontally and vertically across organisations.

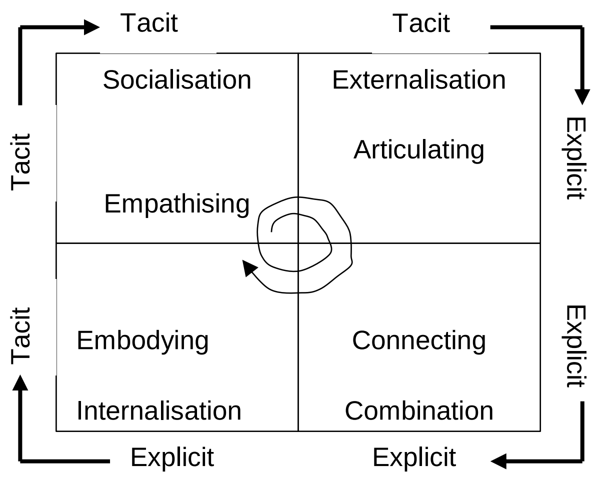


Figure 2. 5: The SECI model showing the modes of knowledge conversion
(Source: Nonaka and Takeuchi, 1995; Nonaka et al., 2000)

It is a dynamic process, starting at the individual level and expanding as it moves through communities of interaction that transcend sectional, departmental, divisional and even organisational boundaries. Organisational knowledge creation is a never-ending process that upgrades itself continuously.

This interactive spiral process takes place both intra- and inter-organisationally. Knowledge is transferred beyond organisational boundaries, and knowledge from different organisations interacts to create new knowledge. Through dynamic interaction, knowledge created by the organisation can trigger the mobilisation of knowledge held by outside constituents such as consumers, affiliated companies, universities or distributors. For example, an innovative new manufacturing process may bring about changes in the suppliers' manufacturing process, which in turn triggers a new round of product and process innovation at the organisation. Another example is the articulation of tacit knowledge possessed by customers that they themselves have not been able to articulate. A product works as the trigger to elicit tacit knowledge when customers give meaning to the product by purchasing, adapting, using, or not purchasing it. Their actions are then reflected in the innovation process of the organisation, and a new spiral of organisational knowledge creation starts again.

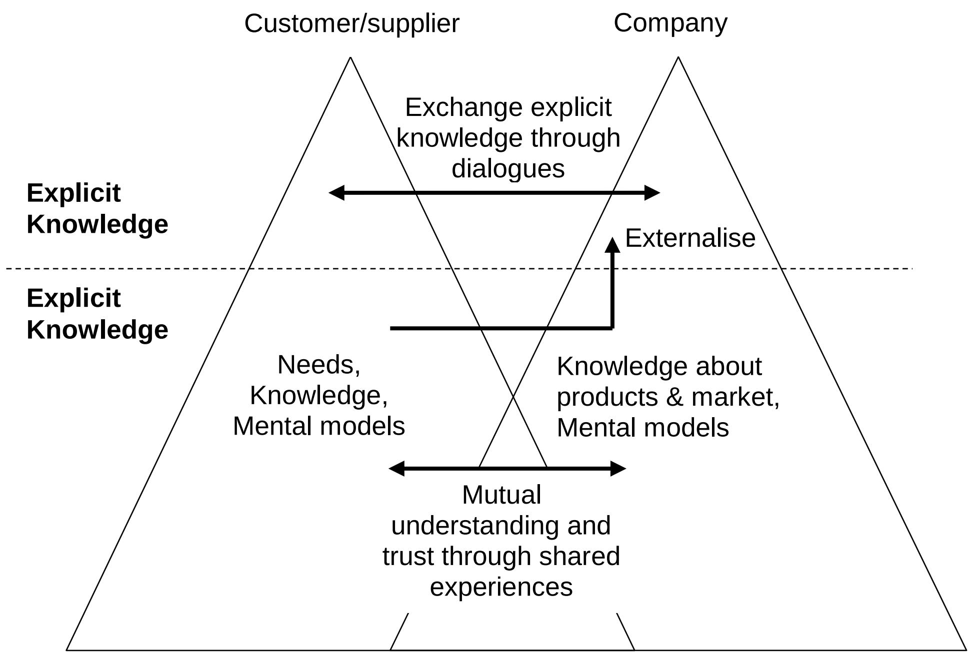


Figure 2. 6: Creating knowledge with outside constituents
(Source: Nonaka et al., 2000)

Figure 2.6 shows how the organisation interacts with outside constituents to create knowledge. Knowledge creation is a self-transcending process, in which individuals reach out beyond the boundaries of their own existence. In knowledge creation, individuals transcend the boundary between themselves and others, inside and outside, past and present. In socialisation, self-transcendence is fundamental because tacit knowledge can only be shared through direct experiences which go beyond individuals. For example, in the socialisation process people empathise with their colleagues and customers, which diminish barriers between individuals. In externalisation, an individual transcends the inner- and outer-boundaries of the self by committing to the group and becoming one with the group. Here, the sum of the individuals' intentions and ideas fuse and become integrated with the group's mental world. In combination, new knowledge generated through externalisation transcends the group in analogue or digital signals. In internalisation, individuals access the knowledge realm of the group and the entire organisation. This again requires self-transcendence, as individuals have to find themselves in a larger entity.

2.2.2.1 Implicit and Explacit knowledge

Despite the wide adoption of the SECI model, it is important to recognise the debates relating to the tacit-explicit knowledge dichotomy. One of such debates suggests that rather than tacit and explicit knowledge representing separate and distinct types of knowledge, they represent two aspects of knowledge and are in fact inseperable, and are mutually constituted (Tsoukas, 1996; Werr and Stjernberg, 2003). One consequence of this is that there is no such thing as fully explicit knowledge as all knowledge will have tacit dimensions. Clark (2000) uses the term ‘explacit knowledge’ to linguistically symbolise their inseparability for example text which is often referred to as a form of codified knowledge has tacit components without which no reader could make sense of it. Examples of these tacit elements include an understanding of the language in which they are written and the grammar or syntax used to structure them. Polanyi (1969, 1985) suggests that ‘the idea of a strictly explicit knowledge is indeed self-contradictory; deprived of their tacit coefficients, all spoken words all formulae, all maps and graphs are strictly meaningless’. While Polanyi’s work is often used to justify the tacit-explicit dichotomy, a number of authors suggest that this misunderstands his analysis (Brown and Duguid 2001; Prichard 2000).

Other debates surround the notion that the tacit-explicit characterisation is rather too simplistic. According to Sternberg and Horvath (1999), a much more nuanced and useful characterisation is to describe knowledge as explicit, implicit, and tacit. Explicit represents knowledge that is set out in tangible form. Tacit represents knowledge that one would have extreme difficulty operationally setting out in tangible form. Implicit however should represent knowledge that is not set out in tangible form but could be made explicit (Benjamin and Shepherd, 2003; Goujon et al., 2014; Bates, 2015). It would seem that the implicit concept represents the cognitive dimension to knowledge which can be articulated unlike the technical dimension which is difficult to articulate. This debate therefore reinforces the SECI model rather than disprove it.

2.2.3 Adopting a knowledge management process

It has been established that despite the magnitude of research and available literature on knowledge management there is yet to be a succinct definition of the term neither is there consensus on what constitutes a good definition. What is even more daunting is the lack of common terminology describing the knowledge management process and sub-processes. In addition to the complexity, there is no agreed sequence to the sub-processes neither is it clear if the sub-processes should be cyclic. It is therefore important to examine the processes presented by authors. A sample is drawn from the processes and sub-processes presented by authors particularly in the past two decades when knowledge management gained popularity in the industry and academia. A sample of the definitions is shown on Table 2.3. Observing the table critically, it is quite daunting to compare one author's presentation with another for several reasons one of which is the variation in the use of terminology. Van der Spek and Spijkervet (1995) presented KM as a process of 'creating knowledge', 'securing knowledge', 'distributing knowledge', and 'retrieving knowledge'. The 'distributing knowledge' aspect of the definition for example is also termed 'disseminate' (Wiig 1997, Shapiro 1999, Behin 2005), 'deploy' (Egbu et al. 2001, Preece 2001), 'diffuse' (Ten Have et al. 2003). All these refer to the same process of spreading or dispersing knowledge. It can be observed that there are overlaps in terminology. Swan et al. (2000) identified 'sharing' and 'using' of knowledge as part of the KM process, similarly, Tiwana (2002) identified 'sharing' and 'utilisation'.

It can be argued that 'sharing' is a subset of 'utilisation', therefore comes under the 'utilisation' sub-process and not at per with 'utilisation' within the KM process cycle. Another observation from the table is the disparity in the sequence of KM processes. Wiig (1997) and Bhatt (2001) commenced the KM process with the creation of knowledge. Wunram (1999) began with identification of knowledge while Holsapple and Joshi (2000) began with acquisition of knowledge. Davenport (1994) offered the still widely quoted definition: ‘Knowledge management is the process of capturing, distributing, and effectively using knowledge’. A total of 42 terminologies for KM sub-processes were identified from the definitions shown in Table 2.4. Eight (8) distinct sub-processes emerged namely: 'identify', 'capture', 'codify', 'store', 'access', 'exploit', 'create', and 'assess'. Other sub-processes or terminologies can be classified under the 8 sub-processes as follows:

Table 2. 3: A Sample of definitions of knowledge management

Author(s)	Knowledge management processes
Van der Spek and Spijkervet (1995)	Identified four areas within the process as: creating knowledge, securing knowledge, distributing knowledge, retrieving knowledge
Coombs (1997)	Reviewed the common dimensions with KM processes and identified four common processes; capture or retrieval of knowledge, modifying knowledge format, validation of knowledge and making the knowledge of the appropriate context.
Liebowitz (1997)	Formulated a nine-step KM approach from a process perspective: transform information into knowledge, identify and verify, capture and security, organisation, retrieval and application, combinations, creation, learning, selling/distributing.
Wiig (1997)	Identified four activities, with a focus on the knowledge itself: creation and sourcing, compilation and transformation, dissemination, application and value realisation.
Davenport and Prusak (1998)	KM systems involve the following processes: generation, codification and coordination, transfer
Shapiro (1999)	Identified four steps in inter project learning from a KM perspective: abstractions and generalisations, embodiment of learning, dissemination of learning and application of learning.
Swan et al. (2000)	Defined KM as: process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides to enhance learning and performance in organisations
Wunram (1999)	Presented seven elements: identification, acquisition, generation, structuring, storing, distribution, and assessment/evaluation.
Studer et al. (2000)	Focused on acquiring, maintaining and accessing weakly structured information sources via three processes: acquiring, maintaining and accessing knowledge.
Holsapple and Joshi (2000)	Presented six activities: acquiring knowledge, selecting knowledge, internalising knowledge, using knowledge, generating knowledge, externalising knowledge
Bhatt (2001)	KM processes involve the five areas: creation, validation, presentation, distribution, application
Egbu et al. (2001)	Five processes of KM were identified as: creating knowledge, identifying knowledge, strategising knowledge, mobilising knowledge, deploying knowledge
Preece (2001)	Identified three key facets to KM: knowledge capture, knowledge storage and knowledge deployment
Robinson et al. (2001)	Identified five distinct but interrelated processes: discovering and capturing, organisation and storage, distribution and sharing, creation and leverage, archiving and retirement
Tiwana (2002)	KM process consists of three areas: acquisition, sharing, utilisation
Ten Have et al. (2003)	Characterised KM process in terms of the ‘learning organisation', this consists of four sub-processes: absorption, diffusion, generation and exploitation of knowledge.
(Behin 2005)	Developed the knowledge virtuous circle, comprising six KM functions: acquiring skills, developing skills, building knowledge, applying knowledge, codifying knowledge and dissemination of knowledge.
Jashapara (2011)	Defined KM as the effective learning process associated with exploitation and sharing of human knowledge that use appropriate technology and cultural environments to enhance an organisation's intellectual capital and performance

Table 2. 4: Knowledge management process and sub-processes (overleaf)

KM Process Selected terminology	Terminology found in literature	Van der Spek & Spijkervet (1995)	Coombs (1997)	Liebowitz (1997)	Wiig (1997)	Davenport and Prusak (1998)	Shapiro (1999)	Wunram (1999)	Studer et al. (2000)	Holsapple and Joshi (2000)	Armbrecht (2001)	Bhatt (2001)	Egbu et al. (2001)	Preece (2001)	Robinson et al. (2001)	Vorbeck and Fenke (2001)	Tiwana (2002)	Shapiro (1999); Ten Have et al. (2003)	(Behin 2005)	Jashapara (2011)	Total from sample
1. Identify	Identify			✓				✓					✓								3
	Source				✓																1
	Select									✓											1
	Discover														✓						1
2. Capture	Capture		✓	✓								✓		✓	✓						5
	Acquire							✓	✓	✓							✓		✓		5
	Absorb																	✓			1
	Abstract						✓														1
3. Codify	Codify					✓													✓		2
	Modify		✓																		1
	Organise			✓																	1
	Transform			✓																	1
	Compile				✓																1
	Coordinate					✓															1
	Structure							✓													1
	Develop																		✓		1
	Filter										✓										1
4. Store	Store							✓				✓		✓		✓					4
	Maintain								✓												1
	Secure	✓																			1
5. Access	Access								✓												1
	Retrieve	✓	✓	✓																	3
6. Exploit	Exploit																	✓		✓	2
	Disseminate				✓		✓												✓		3
	Share														✓		✓			✓	3
	Transfer					✓															1
	Distribute	✓		✓								✓			✓	✓					5
	Sell			✓																	1
	Deploy												✓	✓							2
	Diffuse																	✓			1
	Mobilise												✓								1
	Learn			✓																	1
	Use									✓											1
	Re-use										✓										1
	Apply			✓	✓		✓					✓							✓		5
	Leverage														✓						1
	Strategise												✓								1
	Utilise															✓	✓				2
7. Create	Create	✓		✓	✓						✓	✓	✓		✓	✓					8
	Generate					✓		✓		✓								✓			4
8. Assess	Assess							✓			✓										2
	Validate		✓									✓									2

1. ‘Identify’ involves recognising sources and types of knowledge for the benefit of an organisation particularly in supporting business processes (Lytras et al., 2002; Liebowitz, 1999). Other terms used by authors to describe the same process include 'source', 'select', 'explore' and 'discover'
2. ‘Capture’ involves the act of recording identified knowledge in organisational files and knowledge bases. Collison and Parcell (2001) describe knowledge capture as a means capturing know-how in such a way that it can be reused. Powers (2005) suggests that one of the first steps in capturing knowledge is to identify the critical knowledge that might be at risk in an organisation e.g. effect of downsizing or retirements. Other terms used by authors include 'collect', 'acquire', 'absorb' and 'abstract'
3. ‘Codify’ is the acquisition of knowledge from its source in the most efficient way possible in order to permit knowledge re-usability within the organisation (Lytras et al., 2002). The purpose of knowledge codification is to capture past experiences and make them available in the present either to those who were part of the original experience itself or to an entirely new set of employees altogether (Holthouse, 1999). Other terms used by authors for the same purpose include 'classify', 'modify,' 'organise', 'transform', 'compile', 'coordinate', 'structure', 'develop', 'focus', and 'filter'
4. ‘Store’ involves retaining knowledge in an organisational memory unit or knowledge base Robinson et al. (2001). Other terms used include 'maintain', 'archive', and 'secure'.
5. ‘Access’ refers to the ease of location and retrieval of the right knowledge to the right people at the right time (Studer et al., 2000). This also termed 'retrieve' by authors.

6. ‘Exploit’ involves the optimal use of knowledge for organisational and individual benefits. It includes activities facilitates the knowledge conversion process (Nonaka and Takeuchi, 1995) at individual, organisational or inter-organisation levels.Knowledge exploitation involves several sub-processes which have been identified by authors as: 'disseminate', 'share', 'transfer', 'distribute', 'sell', 'deploy', 'diffuse', 'mobilise', 'learn', 'use', 're-use', 'apply', 'leverage', 'strategise' and 'utilise'.
7. ‘Create’ is the strategic organisational ability to bring into existence and originate new knowledge continuously and repeatedly in a circular process with no ultimate end (Egbu et al., 2001; Storey and Quintas, 2001). Knowledge creation involves the generation and discovery of new knowledge. According to Takeuchi (1998) knowledge creation should be viewed as a process whereby the organisation amplifies the knowledge created by employees and crystallises it as part of the knowledge network of the organisation. Similarly Tiwana (2002) stated that a successful KM project must begin with knowledge that already exists, deliver initial results, and then continue to expand. New knowledge is usually created as one of the outcomes of managing existing knowledge. Other authors use the synonym ‘generate’.
8. Assess: refers to the measurement and benchmarking of KM outcomes within an organisation. Authors have use the terms 'validate', 'evaluate' and 'measure'

The 8 sub-processes can be further classified under 3 main headings (Figure 2.7):

1. Knowledge acquisition – the process of absorbing and storing knowledge, the success of which is often gauged by how well the knowledge can later be retrieved. Sub-processes 1-5 fit into knowledge acquisition (i.e. identify, capture, codify, store, access)
2. Knowledge exploitation – involves optimal unitisation of knowledge for the benefit and profit of an organisation. Sub-processes 6-7 belong to this category (e.g. disseminate, share, transfer, create new knowledge)
3. Knowledge evaluation – a systematic determination of merit using criteria governed by a set of standards which assists an organisation to ascertain the degree of achievement or value in regards to the aim and objectives of an undertaken project. Sub-process 8 belong to this category (i.e. validate, evaluate, measure)

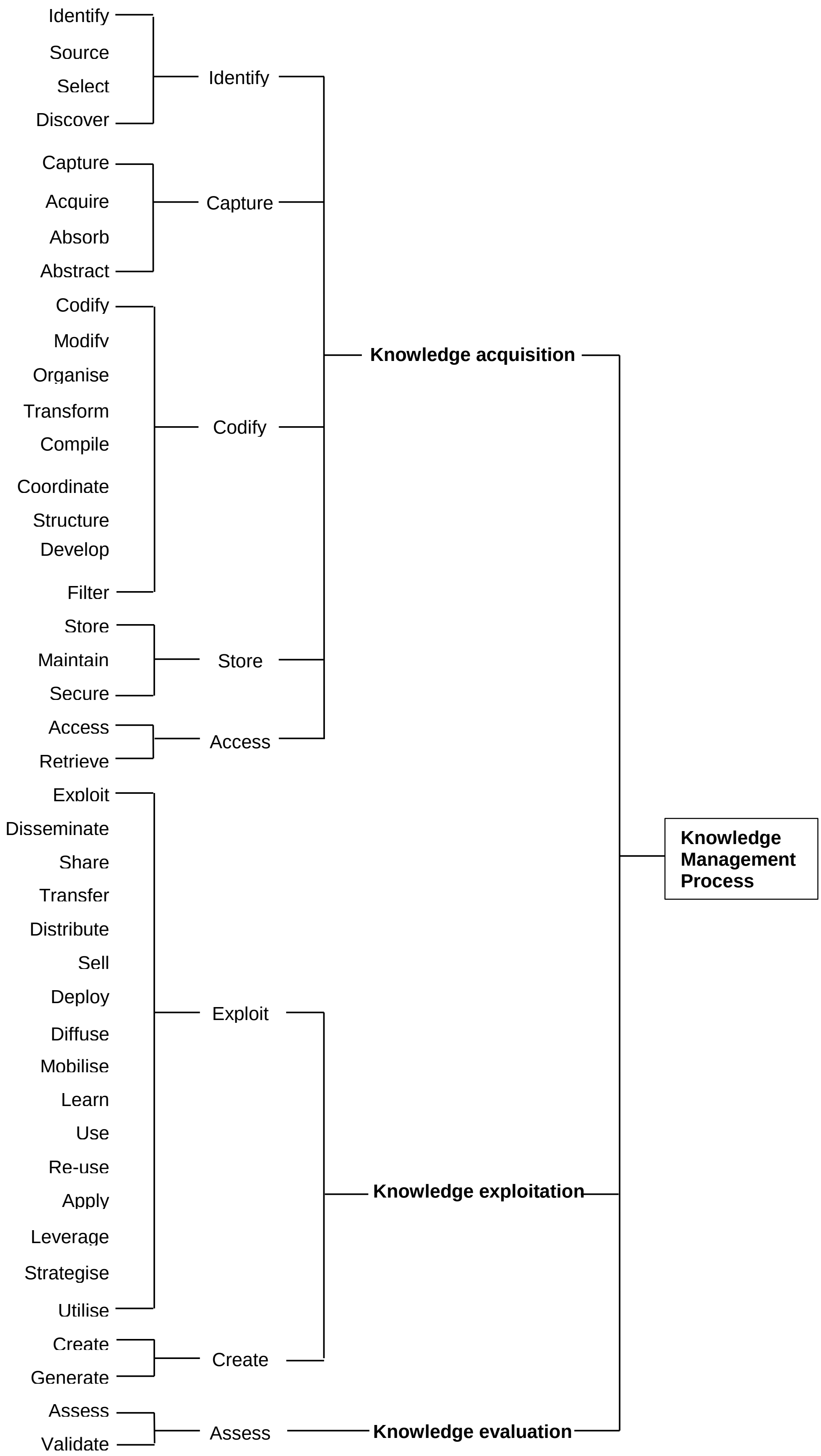


Figure 2. 7: KM sub-process classification based on author definitions

2.2.4 Utilising knowledge management tools

Knowledge management processes are typically supported by tools (Piorkowski et al., 2013). The complexities encountered in defining knowledge and knowledge management extend to the definition of tools as there is no consensus to what constitutes a knowledge management tool. Attempt has been made by authors to define tools as all those instrument that include anything that serves as a means for performing functions, processes, operations or tasks in KM. These tools have the capability to integrate, classify, and codify knowledge from various sources, the ability to enable search retrieval and discovery knowledge, and the capacity to support knowledge sharing between people or other agents (Wensley, 2000; Benbya et al., 2004). Some authors use the term KM tools to mean IT tools, however this would be erroneous as it was identified that not all KM tools are IT-based as everyday tools such as papers, pens, and videos can be utilised to support KM. Some authors define tools as technologies for example Ruggles (1997) described tools as the technologies used to enhance and enable the implementation of knowledge management sub-processes (e.g. knowledge generation, codification, and transfer). Some authors refer to tools as techniques or use the two terms interchangeably. Wenger et al., (2002) referred to techniques as procedures and methods by which knowledge is managed often through the use of tools. This brings about the questions: what are the differences between tools, techniques and technologies? What is the role of IT in KM?

According to Al-Ghassani (2002) KM tools refer to both non-IT tools and IT tools. To distinguish between them, the terms ‘KM techniques’ and ‘KM

Technologies' were used to represent 'non-IT tools' and 'IT tools' respectively. KM techniques have more involvement of people and focus on tacit knowledge for example brainstorming, communities of practice and face to face interactions. KM technologies require IT infrastructure and have more focus on explicit knowledge for example intranets and knowledge bases. This view is supported by other authors but using different terminologies. The terminologies used to refer to non-IT and IT tools include 'personalisation' and 'codification' tools (Hansen et al.,1999; Dingsoyr, 2002; Love et al., 2005), 'soft' and 'hard' (Sveiby, 2001), 'organic' and 'mechanistic' (Kamara et al., 2002), 'people track' and 'IT track' (Sveiby, 2002). The main differences between KM techniques and technologies are presented in Table 2.5.

Table 2. 5: The main differences between KM techniques and technologies
(Source: Al-Ghassani, 2002)

KM tools	
KM techniques	**KM technologies**
• Require strategies for learning • More involvement of people • Affordable to most organisations • Easy to implement and maintain • More focus on tacit knowledge	• Require IT infrastructure • Require IT skills • Expensive to acquire and maintain • Sophisticated implementation and maintenance • More focus on explicit knowledge

There exists a wide range of techniques and technologies available to support knowledge management. Unlike techniques, technologies are made up of hardware and software. Hardware technologies are very important for a KM system as they form the platform for the software technologies to perform and the medium for the storage and transfer of knowledge. Examples of the hardware requirements for a KM system are personal computers and network servers. Software technologies however deal more with IT content which play an important part in facilitating the implementation of KM. Examples of KM techniques and technologies are described in Tables 2.6 and 2.7 respectively.

Table 2. 6: Examples of knowledge management techniques

KM techniques	**Description**
Apprenticeships	Form of training in a particular trade carried out mainly by practical experience or learning by doing (not through formal instruction). Apprentices often work with their masters and learn craftsmanship through observation, imitation, and practice.
Brainstorming	Process where a group of people meet to focus on a problem, or idea, and explore such ideas with a view to coming up with solutions, or further developing the ideas.
Communities of practice	Also called knowledge communities, knowledge networks, learning communities, communities of interest and thematic groups. These consist of a group of people of different skill sets, development histories and experience backgrounds that work together to achieve commonly shared goals
Face-to-face interactions	Traditional approach for sharing the tacit knowledge (socialisation) owned by an organisation’s employees. It usually takes an informal approach and is very powerful
Mentoring	Process where a trainee or a junior staff is attached or assigned to a senior member of an organisation for advice related to career development. The mentor provides a coaching role to facilitate the development of the trainee by identifying training needs and other development aspirations.
Post project reviews	Debriefing sessions used to highlight lessons learnt during the course of a project. These reviews are important for knowledge capture
Recruitment	Easy way for knowledge buy-in. This is a ‘tool’ for acquiring external tacit knowledge especially of experts. This approach adds new knowledge and expands the organisational knowledge base. Members within the organisation can also learn from the recruited member formally and informally so that knowledge will be transferred and retained if the individual leaves the organisation.
Training	Helps in improving staff skills and therefore increasing their knowledge. Its implementation depends on plans and strategies developed by the organisation to ensure that employees’ knowledge is continuously updated.

The challenge for organisations lies in the selection of the appropriate tools for knowledge management (Choudhary et al., 2013; Pietrzak et al., 2015). Different tools may be required to support different aspects of the knowledge management sub-processes of knowledge identification, capture, codification, storage, access, exploitation (e.g. sharing, dissemination), knowledge creation and assessment. The appropriate tool for knowledge storage for example could be the use of a knowledge base (technology) while that of knowledge codification could lie in the use of data/text mining (technology). The tool for knowledge sharing could be the use of communities of practice (technique).

Table 2. 7: Examples of knowledge management technologies

KM technologies	Description
Data and text mining	Extracting meaningful knowledge from masses of data or text. Data are single facts (structured) about events while text refers to unstructured data. The process of data/text mining enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases or 'knowledge-bases'. The approach is also very useful for identifying hidden relationships between data and hence creating new knowledge
Groupware	Software product that helps groups of people to communicate and share information. Useful for group decision-making. Supports distributed and virtual project teams where team members are from multiple organisations and in geographically dispersed locations. Groupware tools usually contain email communications, instant messaging, discussion areas, file area or document repository, information management tools
Intranet/extranet	Inter-organisational network that is guarded against outside access by security tools called firewalls. Extranet is an Intranet with limited access to outsiders, making it possible for them to collect and deliver certain knowledge. Useful for making organisational knowledge available to geographically dispersed staff members and is therefore used by many organisations.
Knowledge bases	Repositories that store knowledge about a topic in a concise and organised manner. They present facts that can be found in a book, a collection of books, web sites or even human knowledge.
Knowledge maps	Used to locate sources of knowledge and experience within or outside an organisation. Knowledge maps are created by transferring aspects of knowledge location and type into a graphical form resulting in a map of where knowledge resides within and outside of the organisation. Knowledge maps can point to people, documents and databases
Taxonomy/ontologies	Collection of terms and the relationships between them that is commonly used in an organisation. Examples of a relationship are hierarchical, functional and networked. Ontologies support deep (refined) representation (for both descriptive and procedural knowledge) of each of the terms (concepts) as well as defined domain theory or theories that govern the permissible operations with the concepts in the ontology.

The selection of techniques and technologies is informed, for example, by the type of knowledge management sub-process to be supported, the nature and location of knowledge the capabilities of the tool and most importantly the goal of adopting knowledge management and how it fits into the overall organisational strategy (Lefika and Mearns, 2015).

2.2.5 Aligning knowledge management with organisational strategy

Knowledge management has been linked to business performance therefore making the case for its adoption in organisational strategy (Carrillo et al., 2003;

Nonaka and von Krogh, 2009; Ollila et al., 2015). According to Kluge et al., (2001) knowledge is at the heart of much of today's global economy, and managing knowledge has become vital to organisational success. The question therefore is: how can organisations systematically exploit all dimensions of knowledge and fully utilise them to improve revenues, profits and growth? The solutions are perhaps embedded in the context that organisations have widely different goals, scope, and success criteria for knowledge management. Failure or successes will be dependent on the set criteria. It is therefore important to examine the aspects relating to knowledge management and organisational strategy. The aspects are:

- Drivers of knowledge management
- Enablers of knowledge management
- Barriers of knowledge management
- Benefits of knowledge management

2.2.5.1 Drivers of knowledge management

Drivers refer to the catalysts for the implementation of knowledge management i.e. those market catalysts that make knowledge management imperative for organisations to maintain or improve their competitive market position (Du Plessis, 2005; Argote and Miron-Spektor, 2011; Budihardjo 2015). A simplistic question to be asked therefore is 'what drives organisations to adopt and implement knowledge management strategies?' One of such drivers is the need to leverage knowledge. Knowledge can be leveraged from both inside (e.g. employees and internal customers) and outside (shareholders and customers) of an organisation. In the current knowledge era, knowledge is being treated as a key asset and thus competitive advantage can be achieved by sharing knowledge internally with employees and externally with customers and stakeholders (Liebowitz, 2000; Love et al., 2005; Nitzan and Procaccia, 2015). Organisations are driven to acquire knowledge from valued individuals and to analyse business activities in order to learn from both successes and failures which in turn leads to continuous improvement and profitability. This leads to another driver which is the need to improve business performance. Markets change rapidly demanding shorter development times and product lifecycles, as a result knowledge management aids research and development and operations necessary to achieve reduced development times including up-to-date reviews of customer behaviour and strategic activities of competitors. (O'Leary, 2001; Armbretch, 2001; Liebowitz, 2002; Chua, 2004; Love et al 2005; Chen and Fong, 2015). From a resource based view, by sharing best practices across an organisation, the performance of the less well performing units can be brought closer to that of the best.

Constant re-organisations mean that the relationships in which informal knowledge is shared are often broken; some organisations have a demographic situation in which many experienced and knowledgeable staff will reach retiring age within a short period of time. Recognising that expertise critical to the organisation's core competencies is held within an ageing and perhaps mobile workforce prompts serious and valid concerns regarding retention of this important knowledge serves as the key driver for implementing knowledge management (Johne, 2001; Wilson, 2001; Rumizen, 2002; Liebowitz, 2002; Mason, 2003; Widmer, 2005; Tubigi and Alshawi, 2015). Globalisation and a distributed workforce have placed businesses everywhere in a new and different competitive situation, where integrating knowledge provides the competitive edge. A key feature of globalisation is the distributed nature of an organisation's employees and the increasing complexity of organisations resulting in more complicated and risky decision-making (Metaxiotis 2003; Galati, 2015). Knowledge management coupled with appropriate technology provides the capability for organisations to work effectively across continents and time zones with a distributed workforce, using appropriate telecommunications (Chua, 2004) and virtual teams (Satyadas, 2001). In effect knowledge management can be used to leverage global capabilities of an organisation for the purposes of getting the right experience to the right person at the right time to solve business problems and achieve the required solutions (Behin, 2005; Costa and Lima, 2015)

In the case of staff development, knowledge management can enhance staff capabilities (Liebowitz, 2002; Olomolaiye, 2007), enable employee perform knowledge intensive tasks (Fischer 2001), decrease time to completion (Satyadas 2001) and improve an organisation's ability to disseminate learning effectively from one part of the organisation to others within it (Kakabadse, 2003; Love et al, 2005; Lefika and Mearns, 2015). Knowledge management can provide an environment to foster and enhance skilled people (Sharkie, 2003). Another driver for knowledge management is the need for better enabling technology. The growth of functionality of the internet, including collaborative workspaces, discussion groups, content management systems and portals, makes it easier to assemble and share information across organisational boundaries (Wilson, 2001; Leybourne and Kennedy, 2015). Faster, better, cheaper is the result of more effective innovation.

Table 2. 8: Summary of drivers of knowledge management

Drivers of knowledge management
• Need to leverage knowledge • Need to improve business performance • Need to manage change and restructuring • Need to manage a distributed workforce • Need for staff development • Need for better enabling technologies • Need for innovation

This requires an innovation system that converts knowledge efficiently and effectively into products, services and processes. (Johne, 2001; Wilson, 2001) Knowledge management can play a part in innovation, which is fuelled by working beyond existing norms, social groups and experiences, new ideas can be generated by having access to different experiences and knowledge (Satydas 2001; Scarborough, 2005). The drivers of knowledge management in organisations are summarised in Table 2.8.

2.2.5.2 Enablers of knowledge management

Knowledge management is a complex process which requires support by a strong foundation of enablers. An enabler is a person or organisation that makes it possible for someone else to achieve something (Oxford Dictionary, 2007). In a broader and more applicable sense, the Oxford Dictionary of Business and Management (2009) define enablers as capabilities, forces, and resources that contribute to the success of an entity, program, or project. Enablers are influencing factors that help foster knowledge consistently through the firm by stimulating knowledge creation, protecting knowledge, and facilitating the sharing of knowledge. (Al-Gharibeh 2011)

According to APQC (2000) and Aurum et al. (2007) the enablers for KM are; leadership, culture, measurement, and technology. Each of these must be designed and managed in alignment with the other and in support of the process. Aurum et al. (2007) considered leadership to be the most significant as knowledge management requires a top-down approach for its successful implementation. Nonaka and Toyama (2005) also found that leadership is vital enabler for successful knowledge management. Vitala (2004) defined some dimensions of knowledge leadership as orienteering of learning, creating climate that supports learning, supporting individual and group level learning process and acting as a role model.

Leadership plays various roles in knowledge creating process such as providing vision, creating, energising, enabling and promoting the continuous spiral of knowledge creation. Von Krogh, et al. (2000) similarly stated that managers need to support knowledge creation rather than control it. They identified enablers for strategy and knowledge creation thus: Instill a knowledge vision, manage conversations and mobilise knowledge activists. According to them, good conversations are the cradle of social knowledge in any organisation as they allow the first and most essential step of knowledge creation, which is sharing tacit knowledge within a micro-community. Knowledge Activists are persons who facilitate the knowledge creation process, create right context and globalise local knowledge aiming at transferring locally created knowledge throughout perhaps globally distributed company. Culture is an important enabler concerned with the ‘climate’ of the knowledge sharing environment, as well as the culture in the organisation that promotes the knowledge sharing. Organisational culture is the common belief, conduct rules and values shared by all organisational members (e.g. Hofstede, 1993). According to Wen-bao (2007), organisational culture can be classified into bureaucratic, innovative and supportive. Bureaucratic culture means that most of the work in an organisation is standardised and operates on the basis of control and power (Wen-bao, 2007; Romero, 2014). Tasks are completed in proper sequence and enterprise ethic is specially emphasised. Innovative culture means that the work in an organisation is challenging and innovative in which case organisational members are encouraged for adventure and initiative (Romero, 2014). A supportive culture refers to an open and harmonious working environment in which participation, teamwork and interpersonal relationship are specially emphasised (Man and Luvison, 2014).

According to Jennex and Olfman (2004), an organisational culture should support learning and sharing. Examples of organisational cultures are altruism, reciprocity, trust, repute, openness, solidarity, sociability, motivation, and commitment. Measuring and evaluating knowledge performance are key enablers and important factors that can serve a number of purposes including gathering evidence on the cost and benefits of implementing knowledge management within an organisation, monitoring progress and learning from past activities (Stanfield and Mullan, 2008). It is important for organisations to map out key performance indicators to benchmark the progress of knowledge management activities. Hartz et al. (2001) identified areas desirable for replication and measurement throughout an organisation, they include measurement of business value, retention of knowledge, cultural impact, and effectiveness of sharing communities.

There have been a number of technologies enabling or facilitating knowledge management activities in organisations, including expert systems, knowledge bases, software help desk tools, and document management systems. According to Hein (2004) and Brink (2003), technology supports knowledge by enabling communication, collaboration, storing and retrieval of knowledge. The advent of the Internet brought with it further enabling technologies, including e-learning, web conferencing, collaborative software, content management systems, corporate directories, email lists, wikis, blogs, and other technologies. Each enabling technology can expand the level of inquiry available to an employee, while providing a platform to achieve specific goals or actions. Technology therefore plays a role in integrating knowledge and creating new knowledge within an organisation.

In addition to technology, Al-Gharibeh (2011) highlighted six other enablers of knowledge management namely collaboration, trust, learning, centralisation, formalisation, and T-shaped skills. Collaboration relates to the degree of active support and help in an organisation. Trust refers to degree of reciprocal faith in others intentions, behaviours, and skills toward organisational goals. Learning relates to the degree of opportunity, variety, satisfaction, and encouragement for learning and development in an organisation. Centralisation is degree of authority and control over decisions. Formalisation is the degree of formal rules, procedures, and standard polices. T-shaped skills relates to the degree of understanding of employees own and other’s task areas. A summary of the enablers to knowledge management are summarised in Table 2.9.

Table 2. 9: Summary of enablers of knowledge management

Enablers of knowledge management
• Leadership • Knowledge activists • Organisational culture • Measurement and evaluation • Technology • Collaboration • Trust • Learning • Centralisation • Formalisation • T-shaped skills

2.2.5.3 Barriers to knowledge management

Barriers can be defined as circumstances, situations or people that impede the progress of knowledge management initiatives or activities (Sharma et al., 2012). A number of barriers have been identified from existing literature; one of such is the lack of senior management commitment. Senior management are instrumental in the development of organisational structure, technological infrastructure and various decisions making processes which are essential for effective creation, sharing and use of knowledge.

Effective knowledge creation and sharing require long term commitment and support from top management in recruitment and retention of right people (Brand, 1998; Cheikhrouhou et al., 2013). According to Chong and Choi (2007), lack of top management is the most critical barrier for a successful knowledge management implementation, particularly in knowledge creation and sharing. Senior management therefore have to conceptualise a vision about what type of knowledge should be developed and integrated into a management system for implementation (Nonaka and Takeuchi, 1995; Nonaka et al, 2000; Nonaka and Toyama, 2005).

The role of technology cannot be overlooked in knowledge management. The lack of technological infrastructure therefore is a key barrier in implementation of knowledge management. Technological infrastructure provides a stronger platform to knowledge management and enhances its impact in an organisation, by helping and leveraging its knowledge systematically and actively (Singh and Kant, 2007; Jayaram and Pathak, 2013). The wide varieties of technology such as business intelligence, knowledge base, collaboration, portals, customer management systems, and data mining support knowledge management activities and the selection of appropriate technology improves the performance of businesses (Singh et al., 2007; Dulipovici and Robey, 2013).

Apart from the lack of technology, it was found that the lack of methodology is a barrier. Knowledge management is a group of clearly defined processes or methods used to search important knowledge among different knowledge management operations (Wiig, 1995). Even if there were senior management commitment and technological support, knowledge management initiatives may fail if there is a lack of a well-defined and structured approach to knowledge management. Another barrier is the lack of organisational structure. According to Ebert and Griffin (2005), organisational structure refers to the specification of jobs to be done within an organisation and the ways in which those jobs relate to one another. This includes the division of labour, departmentalisation and distribution of power which is necessary to support the information and decision process of the organisations. Creating an organisational structure is by no means a guarantee for the success of knowledge management, but is an important ingredient for its success (Davenport and Volpel, 2001). Adversarial organisational culture towards knowledge management was identified as a barrier (Chase, 1997; Pugnaa and Boldeanu, 2014). Organisational culture relates to the core beliefs, value norms and social customs that govern the way individuals act and behave in an organisation. It is the sum of shared philosophies, assumptions, values, expectations, attitudes, and norms that bind the organisations together (Lemken et al., 2000). Organisation culture entails the aspects of trust and collaboration.

Trust is one of the aspects of the knowledge friendly cultures that fosters the relationship between individuals and groups, thereby, facilitating a more proactive and open knowledge sharing (Alawi 2007; Robertson et al., 2015). Absence or minimal level of collaboration hinders the transfer of knowledge between individuals and between groups. Organisational goals are sometimes not achieved unless they integrate the concept of motivation and rewards to employees. Lack of motivation and reward system can therefore be a barrier as it discourages people to create, share, and use knowledge. Motivation can be provided through recognition, visibility, and inclusion of knowledge performance in appraisal systems and incentives (Hariharan 2002).

Employees are more likely to share their knowledge easily when motivated (Bhirud 2005; Urbancová and Vnoučková, 2015). Without the establishment of organisational reward and recognition systems, it may be difficult to align knowledge management and business needs of the organisation (Witt, 1999;

Cai et al., 2013). There is the barrier of lack of ownership of problem where no employee is ready to take up the jobs unless it has been properly assigned. This situation makes it difficult to nurture knowledge management within the organisation especially if employees perceive it as an extra task rather than part of the organisational culture, knowledge management presents new ways of decision-making and people have to share knowledge and know-how. Knowledge being often associated with power, promoting knowledge sharing is not an easy task particularly if employees do not see how they can directly benefit from it. Lack of time is regarded as a barrier. Sharing knowledge demands additional effort (Carrillo et al., 2000; Cai et al., 2013). This effort may be minimised by work practices and the introduction of better knowledge sharing tools. Construction projects for example are always working to tight deadlines. Any activity that detracts from the main business is seen as of diminished importance. The barriers to knowledge management are summarised in Table 2.10.

Table 2. 10 Summary of barriers to knowledge management

Barriers to knowledge management
• Lack of senior management commitment • Lack of technological infrastructure • Lack of methodology • Lack of organisational structure • Lack of organisational culture • Lack of motivation and rewards • Lack of ownership of problem • Lack of time

2.2.5.4 Benefits of knowledge management

According to Clark and Soliman (1999), many of the benefits of knowledge management are intangible and difficult to quantify. Since traditional financial measure such as return on asset (ROA) or return on equity (ROE) cannot sufficiently evaluate the intangible aspects of organisational assets, such as knowledge or knowledge workers. Notwithstanding, several benefits have been identified. They include: improved service quality; rapid and effective enterprise-wide problem-solving; improved decision making; increased revenue and business growth; increased innovation; practice and process improvement; higher levels of expertise and knowledge; increased customer satisfaction; enhanced employee capability and organisation learning; increased employee morale, creativity and ingenuity; employee stimulation and motivation; raised company professional image; increased flexibility and adaptability (Beckman, 1997; Wiig, 1999; Liebowitz, 2000; Mousavizadeh et al., 2015).

The benefits of knowledge management are evident in various industry sectors. In manufacturing, knowledge management has been empirically proven to help the improvement of performance in terms of the quality, time, speed and reliability while reducing production costs (Armstead, 1999). In the business sector, the benefits of knowledge management can be measured as a key capability which can generate sustainable competitive advantage (Skryme and Amidon, 1997; Davenport et al., 1998; McCampbell et al., 1999; Soliman and Spooner, 2000). Intellectual capital is one of the measures receiving attention from academia and practice (Edvinsson, 1997). Benefits from KM projects involve money saved or earned (O'Dell and Grayson, 1998; McCampbell et al, 1999). In the construction industry, the key benefits of knowledge management to organisations include: innovation; improved performance; improved construction project delivery; facilitated transfer of knowledge across a variety of project interface; quick response to clients' needs and other external factors; improved support for teams of knowledge workers; retained tacit knowledge; and increased value (Robinson et al., 2001; Al-Ghassani et al., 2004; Carrillo et al., 2004; Egbu, 2004; Anumba et al., 2005; Todorović et al., 2015). The benefits of knowledge management are summarised in Table 2.11.

Table 2. 11: Summary of the benefits of knowledge management

Benefits of knowledge management
• Improved service quality • Increased revenue and business growth • Increased innovation • Improved performance • Increased customer satisfaction • Enhanced employee capability • Employee stimulation and motivation • Raised company professional image • Increased flexibility and adaptability • Reduced production costs • Sustained competitive advantage • Retained tacit knowledge

Table 2. 12: An overview of the strategic aspects considered for KM implementation

Drivers	Enablers	Barriers	Benefits
• Need to leverage knowledge • Need to improve business performance • Need to manage change and restructuring • Need to manage a distributed workforce • Need for staff development • Need for better enabling technologies • Need for innovation	• Leadership • Knowledge activists • Organisational culture • Measurement and evaluation • Technology • Collaboration • Trust • Learning • Centralisation • Formalisation • T-shaped skills	• Lack of senior management commitment • Lack of technological infrastructure • Lack of methodology • Lack of organisational structure • Lack of organisational culture • Lack of motivation and rewards • Lack of ownership of problem • Lack of time	• Improved service quality • Increased revenue and business growth • Increased innovation • Improved performance • Increased customer satisfaction • Enhanced employee capability • Employee stimulation and motivation • Raised company professional image • Increased flexibility and adaptability • Reduced production costs • Sustained competitive advantage • Retained tacit knowledge

2.3 APPLICATION OF KNOWLEDGE MANAGEMENT IN CONSTRUCTION

This section addresses the following areas of inquiry relevant to the application of knowledge management e.g. How is knowledge applied in the construction industry? What is the significance of knowledge management in the construction supply chain? What are the knowledge types relevant to construction management? How is knowledge harnessed and integrated in construction management? What are the issues relating to knowledge management in construction?

2.3.1 Overview of the UK construction industry

The UK construction industry's significance is due not only to the fact that it provides the buildings and infrastructure on which virtually every other sector depends, but to the fact that it is such a sizeable sector in its own right.

Construction contributes £90 billion gross value added to the UK economy (nearly 7% of the total), comprises over 280,000 businesses and accounts for 3 million jobs; this is equivalent to about 10% of total UK employment (HM Government, 2013). Despite its enormous size, the construction industry is overwhelmingly made up of small, local firms with fewer than 20 employees, and a few larger firms employing thousands of people. For a regional project, the subcontract size may be even smaller, with examples of projects where 70% of sub-contracts were below £10,000. Because of the very large number of small firms, the industry is often characterised as unconcentrated. This is clear evidence of the fragmentation of the industry and a real demonstration of the challenge of building integrated supply chains with a close focus on the end product and customer value.

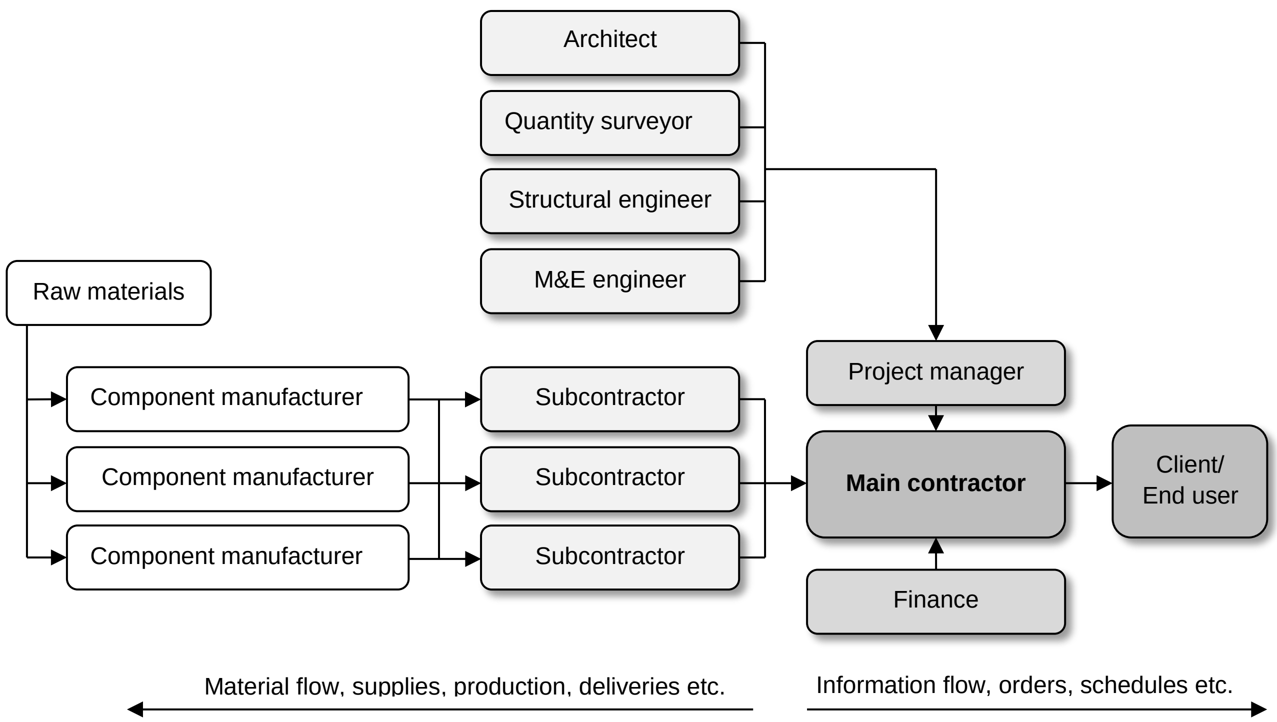


Figure 2.8: A simplified representation of the construction supply chain
(Source: BIS 2013)

There are limited numbers of general contractors who are capable of managing very large projects, whereas there are large numbers of small subcontractors. The large contractors however engage the small and medium size contractors on large construction projects. According to EC Harris (2013), in a typical large building project (i.e. £20 - £25 million range), the main contractor may be directly managing around 70 sub-contracts of which a large proportion are small organisations (£50,000 or less). Figure 2.8 shows a simplified representation of the construction supply chain although in practice a construction project may rely on tens of subcontractors and component manufacturers.

The construction industry is project-based engaging a variety of separate firms in a temporary multidisciplinary organisation, to produce investment goods which are custom built to unique specifications. During project conception, the client establishes the need for a project and develops a set of requirements, which are converted into an appropriate design. At the construction stage, the design is transformed into a facility for the use of the client. Project phases can be simplistically classified into design, construction and handover (See Figure 2.9)

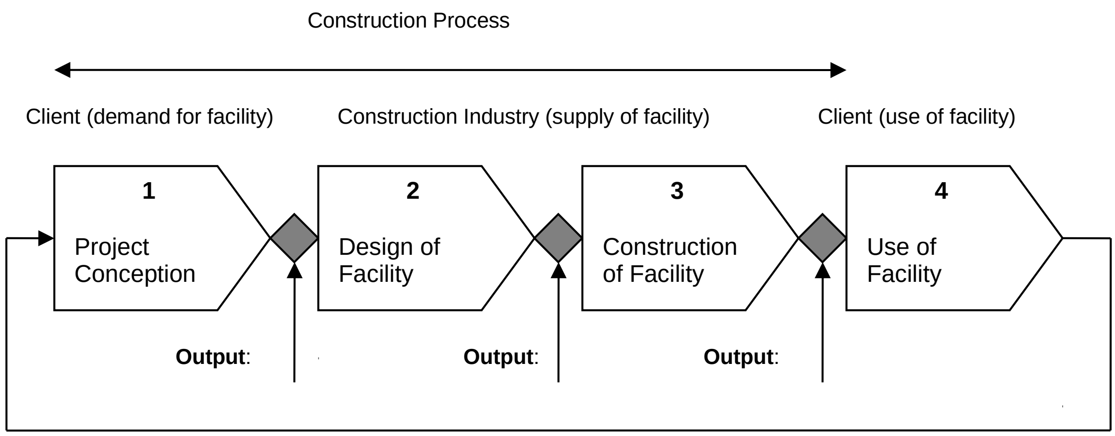


Figure 2.9: Simplified model of construction process
(Source: Kamara et al., 2002)

2.3.2 Application of the SECI model to the construction supply chain

A dominant KM concept is that of knowledge conversion in which new knowledge is created through the interfaces between tacit and explicit knowledge. While explicit knowledge is formal, systematic and can be easily shared, tacit knowledge is personal, hard to formalise and can be difficult to capture or communicate to others (Polanyi 1966, Nonaka and Takeuchi 1995, Nonaka and Toyama 2005). Knowledge conversion is made up of four interfaces known by the acronym 'SECI' model: Socialisation (i.e. the conversion of tacit to tacit); Externalisation (tacit to explicit); Combination (explicit to explicit); and Internalisation (explicit to tacit). The model is often facilitated by KM tools.

According to Al-Ghassani (2002) KM tools refer to both non-IT tools and IT tools. To distinguish between them, the terms 'KM techniques' and 'KM Technologies' were used to represent 'non-IT tools' and 'IT tools' respectively. KM techniques have more involvement of people and focus on tacit knowledge for example brainstorming, communities of practice and face to face interactions. KM technologies require IT infrastructure and have more focus on explicit knowledge for example intranets and knowledge bases. The challenge therefore is to identify and utilise the most effective tools (Oduoza and Harris, 2011; Chong et al., 2013; Fornasiero and Zangiacomi, 2013). The SECI model and tools are applicable to the construction supply chain in facilitating knowledge interactions across personal, organisational, project and industry boundaries (Figure 2.10). They are also applicable to managing construction

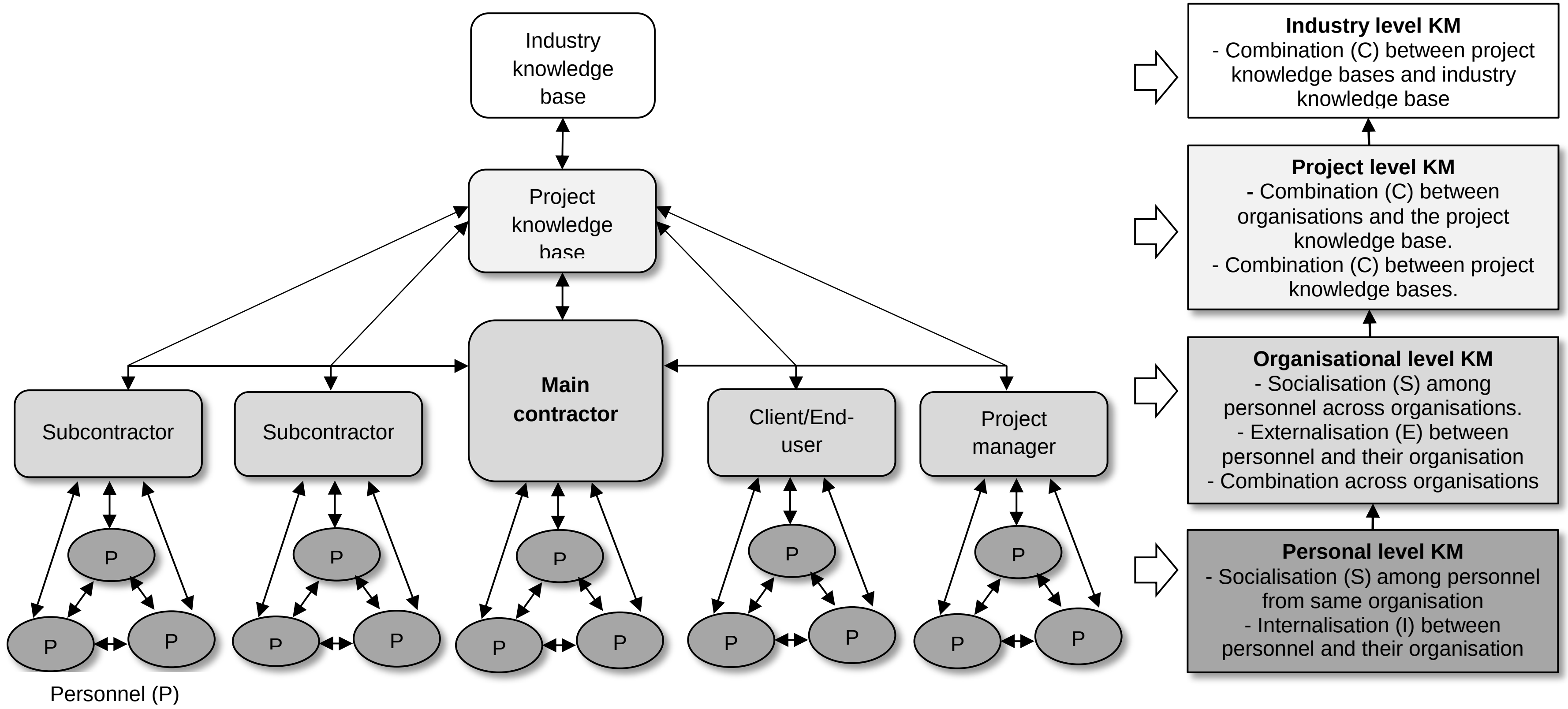


Figure 2. 8: Application of the SECI model to the construction supply chain

challenges such as; the arguably unique characteristics of construction projects, the complicated nature of operations, multitude of professions and organisations, temporary team members, heavy reliance on experience, the one-off nature of the projects, tight schedules and limited budgets (Zin and Egbu, 2011; Tiwari, 2015). The underlying rationale is the need to strategically manage employee-owned tacit knowledge within construction organisations (Carrillo and Chinowsky 2006) and the need for knowledge integration across organisational and project boundaries (Ruan et al. 2012; Garstenauer, 2014) leading to measurable outcomes such as retained knowledge, improved performance, reduced costs, client satisfaction and increased profitability (Armbrecht et al. 2001; Chua 2004, Boyd and Chinyio 2006; Liebowitz, 2009) thereby driving continuous improvement in the industry (Egan, 1998; Smyth, 2010; Shan et al., 2013).

2.3.3 Issues relating to knowledge management in construction

Knowledge management is invaluable to the construction industry as it is deemed critical for construction organisations to harness and integrate knowledge in order to improve efficiency and increase profitability. It is particularly important due to the arguably unique characteristics of projects such as the complicated nature of operations, multitude of occupations, professions and organisations, temporary team members, heavy reliance on experience, one-off nature of projects, tight schedules and limited budgets (Zin and Egbu, 2010). The nature in which the construction industry is organised means that, efficiency in project delivery is less than expected, resulting in dissatisfied clients and low profitability for construction organisations (Egbu *et al.*, 1999;

Carrillo *et al.*, 2000). Clients are becoming more sophisticated, insisting on better value for money, and demanding more units of construction for fewer units of expenditure (Wolstenholme 2009). The demanded products are also becoming more complex, with increasing emphasis on environmentally friendly facilities (Egan 2002; BIS, 2013). The need for knowledge management in construction is therefore driven by the need for innovation, improved project performance and client satisfaction. The Latham report (1994) commenced a new generation of government commissioned reports (see Table 2.13), criticizing the industry and making recommendations for improvement. While Latham (1994) particularly addressed adversarial relations in construction, Egan (1998) was wide-ranging and more relevant to knowledge management as it addressed four key areas namely client leadership, innovation, performance measurement, and dissemination of best practice. Other reports relevant to knowledge management include Egan (2002) and Wolstenholme (2009).

Table 2. 13: A sample of reports critical of UK construction industry

Date	**Report**
1994	The Latham Report, Constructing the Team.
1996	Partnering in the Team, CIB.
1998	The Egan Report, Rethinking Construction.
1999	Achieving Excellence in Construction, Office of Government Commerce.
2001	Modernising construction, National Audit Office. .
2002	Rethinking Construction 2002: Achievements, Next Steps, Getting Involved
2002	Accelerating change: A report by the Strategic Forum for Construction
2002	Fairclough Report, Rethinking Construction Research and Innovation
2005	Be Valuable, Constructing Excellence.
2008	Construction Commitments, Strategic Forum for Construction.
2008	The Strategy for Sustainable Construction, Government/Strategic Forum.
2009	Wolstenholme Report. Never waste a good crisis. Constructing Excellence
2011	Government Construction Strategy, Cabinet Office.
2013	Construction 2025.

In addition to the industry reports, efforts have been made in academia to develop strategies for knowledge management within construction organisations and on projects. The issues addressed include knowledge capture, knowledge sharing, new knowledge creation, techniques and technologies (e.g. Al-Ghassani et al., 2004; Egbu, 2005; Suresh et al., 2008; Carrillo et al., 2013; Ren et al., 2013; Garstenauer, 2014).

Organisations have also made efforts to implement knowledge management strategies; a survey of leading construction organisations in the UK showed that about 42% have a knowledge management strategy, and 32% plan to have a strategy within a short term (Carrillo *et al,* 2004). Over 90% of larger organisations have or intend to have a strategy compared to half of the smaller organisations. A study by Robinson *et al*, (2001) found that for construction organisations, the most important reasons for commencing knowledge management were: dissemination of best practices to key sets of employees, retention of the tacit knowledge of key employees, continuous improvement, the need for quick customer response and the need to share knowledge.

There is an increasing awareness of the need to strategically manage employee-owned tacit knowledge within construction organisations in UK (Carrillo and Chinowsky, 2006) and the need for knowledge integration across personal, organisational and project boundaries (Ruan et al. 2012). This suggests that knowledge management is becoming increasingly important in construction. Knowledge management also appears to be even more important to larger organisations as it is difficult to determine 'who knows what' in such organisations. Larger organisations are also more likely to have a leader or a knowledge management champion and to have the resources to support the strategy.

Despite the knowledge management efforts, the construction industry remains criticised for being poor at learning, often ‘reinventing the wheel’, repeating mistakes and wasting resources (Robertson, 2002; Flar, 2002; Grimaldi and Rippa, 2011). Specialist and technical knowledge is often lost from one project to the next stifling an organisation’s ability to retain and re-use knowledge (Egbu and Botterill, 2000; Akdere, 2009). The project-based, fragmented and unstable nature of the industry has led to significant knowledge loss compared with other industries (Graham and Thomas 2008; Jayaram and Pathak, 2013). The need to attract, retain and develop more of the right people to improve industry capability has also been recognised (Wolstenholme 2009). A summary of the issues relating to knowledge management in construction are summarised in Table 2.14 below.

Table 2. 14: Issues relating to knowledge management in construction

Issues relating to knowledge management in construction
• The construction industry is project-based thereby posing the challenge of knowledge capture, retention and re-use • The industry is fragmented thereby brings about the challenge of knowledge integration across organisations • The industry is criticised for being poor at learning, ‘reinventing the wheel’, repeating mistakes and wasting resources • Multiple organisations are typically involved in a single project creating the challenge of integration and collaborative working with a focus on the end product and customer value • Clients are often dissatisfied with project performance, project process and product quality • Low profitability of organisations as a result of knowledge management related inefficiencies • Larger organisations are more likely to formally practice knowledge management than the majority of small organisations

2.4 SUMMARY OF CHAPTER 2

This chapter examined the existing body of work on knowledge management. It critically reviewed past and current literature on the conceptualisations of knowledge and knowledge management. It was found that knowledge management relates not so much on the justification knowledge but on understanding the uses of knowledge in order to effectively deal with tasks that involve knowledge-based activity. This shaped the direction of the study into focusing on the contemporary definitions, concepts and applications of knowledge management. Knowledge types, sub-types and characteristics were identified. Despite the existence of a plethora of definitions of knowledge management which are daunting and confusing, four commonalities were found: (1) Harnessing and integrating knowledge (2) Adopting a knowledge management process (3) Utilising knowledge management tools, and (4) Aligning knowledge management with organisational strategy. The drivers, enablers, barriers and benefits of knowledge management were identified. The chapter also discussed the application of knowledge management in construction, and presented a model for applying SECI to the construction supply chain. Finally, the issues relating to knowledge management in construction were identified.

CHAPTER 3

A REVIEW OF LITERATURE ON THE COST OF POOR QUALITY

This chapter examines the existing body of work on quality management with a specific focus on the cost of poor quality on construction projects. It discusses the conceptualisations of quality including key definitions and applications. The chapter reviews and presents findings from three case studies obtained from a secondary source which deal with construction stakeholders' influence on the definition of quality on construction projects. It explores the causes of poor quality and examines the resultant costs associated with poor quality on construction projects. It quantifies the cost of poor quality based on the work of previous authors. The chapter explores quality management initiatives and tool used by organisations in reducing costs of poor quality. It finally discusses the issues relating to COPQ in construction project management.

3.1 CONCEPTUALISATIONS OF QUALITY

Quality management can reap benefits such as increased productivity, reduced waste, increased profit, increased customer satisfaction and retention (ISO 9000: 2005) yet defining the term 'quality' itself can be challenging since it is often referred to as perceptual, conditional and a subjective attribute that may be conceptualised in different ways. It is therefore fundamental to examine the conceptualisations of quality before proceeding to the causes and the cost of poor quality on construction projects.'

3.1.1 Definition of quality

There exists a plethora of definitions of quality most of which originate from backgrounds such as manufacturing, operations management and business (Pryzdek and Keller, 2009; Nasim et al., 2014). These definitions date as far back as the 1950s when the quality movement arguably started in Japan and became popular in the United States in the 80s and 90s (Ebrahimi and Sadeghi, 2013; Johnstone, 2015). It is therefore important to review the historical trends in the definition of quality by renowned industry practitioners and academics.

Quality has been defined in various terms such as user-perception, conformance to requirements, zero defects, customer satisfaction, cost reduction and increased profit. Pirsig (1974) like many other philosophers suggested that quality cannot be accurately defined but is a subjective phenomenon that is the emergent emotion resulting from the combination of perception and expectation. The feeling of high quality occurs when perception exceeds expectation; the feeling of low quality occurs when perception does not meet expectation. In this regard, quality in a product or service is not what the supplier puts in but what the customer gets out and is willing to pay for.

A product is therefore not quality because it is hard to make and costs a lot of money, customers pay only for what is of use to them and gives them value (Drucker, 1985; 1999). Crosby (1979; 1996) defined quality as conformance to requirements, zero defects and ‘right the first time’. This means there is no allowable number of errors built into a product or process. Taguchi (1993; 2005) statistically aimed at uniformity around a target value by lowering the standard deviation in product outcomes, and to keep the range of outcomes to a certain number of standard deviations, with rare exceptions. The Six Sigma approach expects six standard deviations, that is, 99.99966% of the products manufactured should be free from defects (Feigenbaum and Feigenbaum, 2009; García-Bernal and García-Casarejos, 2014). A defect is defined as any process output that does not meet customer specifications, or that could lead to creating an output that does not meet customer specifications. Pyzdek (2003) further described the tools applied within a simple performance improvement model known as Define-Measure-Analyse-Improve-Control or DMAIC. The acronym stands for: Define the goals of the improvement activity; Measure the existing system; Analyse the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal; Improve the system; Control the new system. DMAIC is followed by design for Six Sigma (DFSS) principles and practices. DFSS methodology focuses on the Define-Analyse-Design-Verify DMADV approach which builds on the understanding of DMAIC.

The definition of quality is not restricted to conformance to requirements and zero defects; Kano et al. (1984) for instance defined quality in terms of customer satisfaction by distinguishing between three types of product requirements which influence customer satisfaction in different ways when met. They are the ‘must-be requirements’, ‘one-dimensional requirements’, and ‘attractive requirements’. The must-be requirements are basic criteria of a product. Fulfilling the must-be requirements will only lead to a state of ‘not dissatisfied’. The customer regards the must-be requirements as prerequisites, takes them for granted and therefore does not explicitly demand them. Must-be requirements are in any case a decisive competitive factor, and if they are not fulfilled, the customer will not be interested in the product at all. One-dimensional requirements are usually explicitly demanded by the customer. Customer satisfaction therefore is proportional to the level of fulfillment. This means that the higher the level of fulfillment, the higher the customer's satisfaction. Attractive requirements are attributes that provide satisfaction when achieved fully, but do not cause dissatisfaction when not fulfilled

Feigenbaum (1986) integrated economics into customer satisfaction by defining quality as 'best for the customer use and selling price' and quality control as 'an effective method for coordinating the quality maintenance and quality improvement efforts of the various groups in an organisation so as to enable production at the most economical levels which allow for full customer satisfaction'. Costs go down and productivity goes up as improvement of quality is accomplished by better management of design, engineering, testing and by improvement of processes (Deming, 1982; Feigenbaum and Feigenbaum, 2009). Juran and Godfrey (1999) summarised the cost implications of quality (see Table 3.1) in two ways:

1. Higher quality provides greater customer satisfaction thereby increasing income. This implies that providing more and better quality features requires an investment and hence usually involves increase in costs. Higher quality in this sense usually costs more.
2. Quality means freedom from deficiencies and errors that require doing work over again (rework) or that result in field failures and ultimately customer dissatisfaction. This implies that if there are no errors, then the cost of poor quality will be eliminated. In essence, improved quality can mean reduced cost.

Having examined the different perceptions of quality it can be summarised that quality is about meeting and satisfying needs, usually the needs of the paying customer.

Table 3. 1: Cost implications of quality
(Juran and Godfrey, 1999; De Feo and Juran 2010)

Product features that meet customer needs	**Freedom from deficiencies**
Higher quality enables organisations to:	Higher quality enables organisations to:
• Increase customer satisfaction • Makes products salable • Meet competition • Increase market share • Provide sales income • Secure premium prices	• Reduce error rates • Reduce rework, waste • Reduce field failures, warranty charges • Reduce customer dissatisfaction • Reduce inspection, test • Shorten time to put new products on the market • Increase yields, capacity • Improve delivery performance
The major effect is on sales Usually higher quality costs more	Major effect is on costs Usually higher quality costs less

This is validated by the American Society for Quality (ASQ) which defined quality as the characteristics of a product or service that bear on its ability to satisfy stated or implied needs and a product or service free of deficiencies. ISO 9000 (2005) puts this as the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs. In order to meet these needs, organisations adopt a range of management approaches such as the Total Quality Management (TQM). TQM functions on the premise that the quality of the products and processes is the responsibility of everyone who is involved with the creation or consumption of the products or services offered by the organisation. TQM ensures the involvement of all workforce including management, suppliers and customers in order to meet customer expectations (Kemp, 2005; Jafari and Rodchua, 2014; Johnstone, 2015). The European

Foundation for Quality Management's EFQM Excellent Model (2010) further stipulates that 'excellent organisations know that customers are their primary reason for being and strive to innovate and create value for them by understanding and anticipating their needs and expectations'.

Having examined the concepts and definitions of quality the observations are summarised in a matrix shown in Table 3.2. Several attributes of quality emerged from different authors some of which overlap, are similar or repeated. While one author discussed 'appearance', another discussed 'aesthetics', in the same manner, 'serviceability' share similarities with 'maintainability'. Nevertheless, 15 distinct attributes emerged from 21 definitions. There are causal relationships among the attributes, for example 'conformance to requirements' can lead to 'customer satisfaction', in a similar way, 'functional efficiency' can lead to 'cost reduction'. The most recurring attributes (Table 3.2) are customer satisfaction, conformance to requirements, and freedom from deficiencies. The least recurring attributes are durability, performance and reliability. This implies that most definitions of quality point towards keeping the customer satisfied through the provision of superior products and services conforming to requirements and free from deficiencies.

3.1.2 Defining quality in the construction project context

According to Lal (2008), since quality is a measure of the customer satisfaction provided by a product, it should include the following characteristics: functional efficiency, appearance, ease of installation and operation, safety, reliability, maintainability, running and maintenance cost. The above mentioned quality features do not just occur in the product.

Table 3. 2: Attributes of quality

	Literature / Attributes of Quality	Pirsig (1974)	Crosby (1979)	Deming (1982)	Kano et al. (1984)	Drucker (1985)	Feigenbaum (1986)	TQM	ASQ (Glossary)	Six Sigma (1986)	Taguchi (1993)	Owlia & Aspinwall (1996)	Beckford (1998)	Juran & Godfrey (1999)	Maloney (2002)	Yasamis et al. (2002)	Pyzdek (2003)	BS EN ISO 9000:2005	Subir (2005)	Rose, K. H. (2005)	Delgado-Hernandez & Aspinwall (2008)	EFQM (2010)	Total
1	Aesthetics														✓								1
2	Capability																	✓				✓	2
3	Competence							✓				✓						✓				✓	4
4	Conformance to requirements		✓					✓	✓	✓			✓		✓		✓	✓	✓	✓	✓		11
5	Cost reduction					✓	✓							✓									3
6	Customer satisfaction	✓			✓	✓	✓	✓			✓	✓		✓		✓		✓		✓	✓	✓	14
7	Durability														✓								1
8	Fit for purpose								✓					✓									2
9	Freedom from deficiencies		✓	✓				✓		✓	✓						✓	✓	✓				8
10	Functional efficiency											✓											1
11	Increased profit					✓								✓									2
12	Perceived Quality	✓													✓								2
13	Performance							✓															1
14	Reliability														✓								1
15	Serviceability											✓			✓								2

They have to be specially incorporated in the design and a conscious effort is required during manufacture, to achieve them in the actual product. This brings about two facets of quality namely ‘quality of design’ and ‘quality of conformance’. Quality is initially created by the designer in the form if product specifications and manufacturing instructions. The extent to which design is inherently capable of providing user satisfaction can be termed as quality of design, on the other hand, quality of conformance relates to the fidelity with which the product conforms to the design.

As with cost control, the most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of ensuring conformance to these original designs and planning decisions. (Delgado-Hernandez and Aspinwall, 2008; García-Bernal and García-Casarejos, 2014).

Owlia and Aspinwall (1996) presented a classification of quality as; corporate quality, product quality and service quality. Corporate quality refers to the image that customers have of an organisation. Furthermore, quality-conscious companies normally have a strong quality culture, which is helpful for achieving customer satisfaction. The foundations of corporate quality are, therefore, defined at organisational rather than project level. With product quality, the final output of the construction process consists of products and services, customer satisfaction therefore at this level will result from both elements. Service quality is mainly associated with the users and the level of service they receive after the delivery of the product. Parasuraman (1985) suggested ten dimensions for service quality, which according to Maloney (2002), could be adopted in the construction industry. These are performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality.

Construction organisations adopt various methods in assessing quality, one of such is the Design Quality Indicator (DQI) toolkit which interprets quality in buildings in terms of functionality, build quality and impact. Functionality deals with the arrangement, quality and interrelationship of spaces and how the building is designed to be useful to all. Build quality relates to the engineering performance of the building, which includes structural stability and the integration, safety and robustness of the systems, finishes and fittings. Impact refers to a building's ability to create a sense of place and have a positive effect on the local community and environment.

3.1.2.1 'Customer-centric' vs 'Stakeholder-centric' definitions of quality

During the different stages of a construction project i.e. from initiation to handover, a vast number of interests are affected, both positively and negatively (Olander, 2007; Yongjian et al., 2015). Representatives of these interests are referred to as the project's stakeholders. These are individuals and organisations that are actively involved in the project or whose interests may be affected as a result of project execution or project completion (Freeman, 1984; PMI, 2004; Sunindijo, 2015). McElroy and Mills (2000) narrowed the definition into persons or group of people who have a vested interest in the success of a project and the environment within which the project operates. The term 'vested interest' can here be viewed as equal to the key term 'stake' which is the actual or perceived benefits, risks or harms from organisational activities (Donaldson and Preston, 1995; Post et al., 2002; Azam et al., 2015). Stakeholders include clients, project managers, designers, subcontractors, suppliers, funding bodies, users and the community at large (Newcombe, 2003). These can be categorised as people ‘inside’ the project, e.g. designers and contractors; and people ‘outside’ the project, e.g. users and the community (Johnson and Scholes, 1993). The two categories can also be referred to as internal stakeholders e.g. those actively involved in project execution; and external stakeholders e.g. those affected by the project.

Furthermore, Mitchell et al. (1997) categorised stakeholders as dormant, discretionary, demanding, dominant, dangerous, dependent and definitive. Dormant stakeholders possess power to impose their will, but do not have any legitimate relationship or urgent claim. Their power remains unused. Discretionary stakeholders possess the attribute of legitimacy, but they have no power or urgent claim. There is no absolute pressure for managers to engage in an active relationship, although they may choose to do so. Demanding stakeholders possess an urgent claim, but have no power or legitimate relationship. This is bothersome, but does not warrant more than passing management attention.

Dominant stakeholders are both powerful and legitimate. It seems clear that the expectations of any stakeholders perceived by managers to have power and legitimacy will matter. Dangerous stakeholders lack legitimacy, but possess power and urgency. They will be coercive and possibly violent, making the stakeholder ‘dangerous’. Dependent stakeholders have urgent and legitimate claims, but possess no power. These stakeholders depend upon others for the power necessary to carry out their will. Definitive stakeholders are those that possess both power and legitimacy. They are usually members of an organisation's dominant coalition. When such a stakeholder's claim is urgent, managers have a clear and immediate mandate to attend to and give priority to that claim.

Contrary to the definitions of quality as customer satisfaction (e.g. Kano, 1984; Ek and Çıkış, 2015), it appears that in the construction project context stakeholders have influence on how quality is defined. The former can be referred to as 'customer-centric', and the latter 'stakeholder-centric'. This study therefore further investigated stakeholder influence on customer decisions on project process and product quality. This was achieved through three case studies.

3.1.2.2 A review of three case studies on stakeholder influence on quality

A selection of three case studies was obtained from the Commission for Architecture and the Built Environment (CABE) as a source of secondary data to investigate stakeholder influence on quality. CABE was the government's advisor on architecture, urban design and public space in England. Its function was to influence and inspire the people making decisions about the built environment. It championed well-designed buildings, spaces and places, ran public campaigns and provided expert, practical advice. The three case studies were particularly selected due to their relevance to the investigation namely:

(1) Chelsea Barracks re-development, London – a proposed re-development of former army barracks in south-west London into mixed housing

development comprising of luxury flats and affordable flats. This represents a case whereby stakeholders were able to change customer's end product quality even before the commencement of the project.

(2) Cheonggyecheon Restoration Project, Seoul, South Korea – Cheonggyecheon is a 5.8 km creek that was covered with concrete roads and an elevated highway during the post-Korean war economic development. In 2003, a project was initiated to remove the elevated highway and restore the stream to create a public recreation space. This represents a case whereby stakeholders were able to modify the quality of the end product after product commissioning.

(3) Frederick Bremer School in Waltham Forest – School was built as part of the Building Schools for the Future programme (BSF). School was developed to join together two Walthamstow schools, Aveling Park and Warwick Boys. The school was built as part of a redevelopment of the former Hawker Siddley factory site that included the provision of 256 residential units. This represents a case whereby the stakeholders were included right from the concept stage of the project. Stakeholders were involved in the definition of quality. No further changes were made after project completion. The details of the three cases are summarised in Table 3.3.

3.1.2.3 Findings from the case studies

The Chelsea barracks re-development project was ultimately halted and reviewed because of the influence of a coalition of stakeholders including the residents association and the Prince's Foundation. Mitchell et al. (1997) refers to them as definitive stakeholders who possess both power and legitimacy.

Table 3. 3: Case studies on stakeholder involvement and influence in construction quality

	Project Title/Year	Description	Stakeholders	Initial Plan	Stakeholder issues/ influence	Outcome/New Plan	Attributes of quality influenced by stakeholder action
1.	Chelsea Barracks re-development. London/2007-date	Proposed re-development of former army barracks in south-west London into mixed housing development comprising of luxury flats and affordable flats.	Local residents (Belgravia Residents Association), Local authority (Westminster City Council), Commission for Architecture and the Built Environment (CABE), The Prince's Foundation, Greater London Authority, English Heritage	Buildings from 5 to 13 storeys for 638 homes, leisure uses and public space on south-west London site	Local residents complained that: the proposed steel and glass mini skyscrapers did not fit in with the characteristics of the local area; there would be overcrowding with the influx of over 2000 new residents; large public space would be lost	Project was halted and reviewed: 3 apartment blocks were revised from 9 storeys to 4 storeys to match existing adjacent terrace; tallest building on site was reduced from 13 storeys to 8 storey; the affordable housing units were cut by 13% from 638 to 552; central public space was increased from 0.8 hectares to 2.5 hectares; the scheme has been pushed back further 1.2 metres from the main road; new designers were drafted to re-design the public spaces to reflect and commemorate the site's army history.	Aesthetics, Conformance to requirements, Fit for purpose, Functional efficiency, Perceived quality.
2.	Cheonggyecheon Restoration Project, Seoul, South Korea/2005 completed	Cheonggyecheon is a 5.8 km creek that was covered with concrete roads and an elevated highway during the post-Korean war economic development. In 2003, a project was initiated to remove the elevated highway and restore the stream to create a public recreation space	Seoul Mayor, Seoul Metropolitan Government, Citizen's Committee, Union of merchants, Research Corps, General public including school children and older people.	The £550 million urban renewal project is on the site of the stream. Creation of ecologically friendly metropolis, public facilities, such as the Dongdaemun plaza and various seating schemes, and a museum, situated on the embankment	There was limited consideration of certain user groups, for example older people, people with visual impairments and people with mobility problems. In September 2005, a group led a protest march demanding the right to access the new pathways alongside the stream	Lifts were later provided at seven locations, together with free wheelchairs for users with mobility problems. The failure to integrate these needs from the start meant that these final design interventions were bolt-on solutions. E.g. irregular surfaces are uncomfortable for people using wheelchair and poorly-lit, congested tunnels are difficult for people with visual impairments and may be threatening to certain groups.	Capability Conformance to requirements Fit for purpose Functional efficiency

	Project Title/Year	Description	Stakeholders	Initial Plan	Stakeholder issues/ influence	Outcome/New Plan	Attributes of quality influenced by stakeholder action
3.	Frederick Bremer School in Waltham Forest/2008 completed	School was built as part of the Building Schools for the Future programme (BSF). School was developed to join together two Walthamstow schools, Aveling Park and Warwick Boys. The school was built as part of a redevelopment of the former Hawker Siddley factory site that included the provision of 256 residential units.	Head teacher, Administrator, Governor, Head of English, SEN coordinator, ICT manager, Bursar, Head of technology, School support manager, CABE enabler, Technical project manager, Pupils	Simple layout of two three storey teaching wings that are linked by a triple height internal street. Floor to ceiling windows along the southern elevation of the interior street not only draw light into the building but also act to enliven the exterior, connecting inside activity to outside spaces. The landscaping includes a paved courtyard on two levels, integrating an amphitheatre and exterior prayer room.	The client, Waltham Forest Borough Council used the Design Quality Indicator (DQI) assessment at two stages – during the briefing stage and to evaluate proposed designs. Workshops were held with stakeholders. Bidders had been informed through the brief about stakeholder needs, requirements and aspirations. Each design team presented their schemes to stakeholders, who evaluated their designs using the mid-design assessment tool.	Stakeholders clearly and fairly communicated their detailed needs, wants and aspirations to designers: the centrality of the library at the heart of the school, both symbolically and physically; the importance of seeing the industrial nature of the site as a learning opportunity rather than an obstacle; the need to try and integrate and relate the school to its local community context; the need to develop clear lines of sight throughout the school to prevent bullying, including the provision of anti-bullying toilets.	Aesthetics, Fit for purpose, Functional efficiency, Performance.

When such stakeholder's claim is urgent, managers have a clear and immediate mandate to attend to and give priority to that claim as was done in this case. The stakeholders, against the customer's specifications scaled down the scope and quality, and also offset the scheme further away from the road. The Cheonggyecheon Project lacked public consultation. There was limited consideration of certain user groups, for example older people, people with visual impairments and people with mobility problems so their views and needs were not raised. For the scope of the project to be truly public and genuinely designed for everybody was undermined by lack of inclusive planning. This degenerated into a public protest march demanding the right to access the new pathways alongside the stream. As a result they were able to modify and even improve the quality of the scheme through the provision of lifts and wheelchairs. In the Frederick Bremer School case, stakeholders were included from initiation of the project and were given the opportunity to clearly and fairly communicate their detailed needs, wants and aspirations to designers. The inclusion of stakeholders in quality definition was instrumental to the project success.

3.1.2.4 Operational definition for quality

It has been established that construction projects need to engage stakeholders in a dialogue of value delivery to understand what they need from their products and services. This is evident in the Frederick Bremer School case study in which the project success was dependent on the inclusion of all stakeholders. The concept of the customer (or client) as a single entity therefore does not reflect the reality of stakeholder configurations for projects in which case the client is only one stakeholder out of many. This is evident in all the three case studies examined as they revealed the reality of stakeholder power in influencing quality. Quality therefore should not be defined only in terms of customer satisfaction but should be defined in a broader sense to include stakeholders. Moreover since the definition of quality is subjective, an operational definition is put forward for the purpose of this study which is stated as follows:

"Quality in construction is based on an agreed set of criteria defined by internal and external project stakeholders".

The criteria may include conformance to requirements, zero defects, efficient processes, client satisfaction, cost reduction and increased profit (Crosby, 1979; Crosby, 1996; Kano et al., 1984; Taguchi, 1993; ISO 9000: 2005; Gašparík and Gašparíková, 2013; Ek and Çıkış, 2015). Deviation from the set criteria therefore would tend towards poor quality. Poor quality on the contrary can be defined as non-conformance, unfit for purpose, defective, which in turn can result in increased costs, reduced profits, and stakeholder dissatisfaction. This leads to the next question: what are the causes of poor quality?

3.2 CAUSES OF POOR QUALITY IN CONSTRUCTION

There are several causes of poor quality in construction which have been identified and presented by various authors. Griffith (1990) attributed the causes of poor quality to design issues such as: inaccurate or inadequate detailing; incorrectly specified or inappropriate materials and components; inadequate knowledge or disregard for legislation or guidelines; inadequate coordination between client and designers; poor interaction between client, designers and contractors; inadequate supervision by designers; lack of design empathy for construction. Hammarlund and Josephson (1991) researched the causes of poor quality beyond design issues and identified them as: poor skills; defective workmanship; effects in products; insufficient work separation; inadequate construction planning; disturbances in personnel planning, delays; alterations; failures in setting-out; coordination failure. Burati et al. (1992) classified the causes of poor quality at both design and construction stages as: changes (e.g. design revisions, construction methods); errors (erroneous design or construction procedures) and omissions (e.g. omissions of certain steps in design or construction activities

Chung (1999) further elaborated that poor quality can be as a result of: cases defects are found to be the result of: misinterpretation of drawings and specifications; the use of superceded drawings and specifications; poor communication with the architect, engineer, subcontractors and material suppliers; poor coordination of subcontracted work; ambiguous instructions; unqualified operators and workers; inadequate supervision and verification on site. Love et al. (1999) summarised the causes of poor quality as: poor detailing and workmanship; omissions of brief details; lack of attention to quality by consultants; design errors; lack of integration of services to architectural drawings; design changes; poor quality documentation; verbal or undocumented instructions by architect and engineers to contractor; poor skills resulting in defective workmanship; poor motivation levels of workforce. Similarly, Hwang et al. (2009) identified changes, errors and omissions as the main sources of poor quality. Love et al. (2004, 2010), and Jafari and Love (2013) also found that poor quality results from design changes, errors, and omissions that often stem from scope uncertainty and the contracting strategy adopted. The causes of poor quality are shown in Figure 3.1.

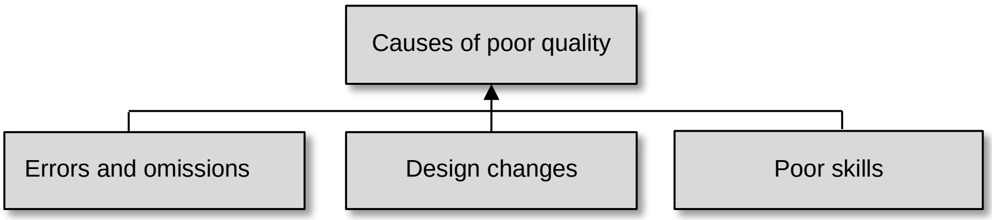


Figure 3. 1: Causes of poor quality on construction projects

The causes of poor quality are in-exhaustive as different projects pose numerous and sometimes unique quality issues. A classification of the causes can however be drawn by examining patterns, similarities and differences identified from the causes presented in previous studies. These are summarised in Table 3.4

3.3 THE COST OF POOR QUALITY

The cost of poor quality (COPQ) situates within the cost of quality (COQ) concept of quality management. COQ has been defined by the American Society for Quality Control (ASQC, 1971) and Total Quality Management 177 BS6143 Part 2 (1990) as the costs incurred in ensuring quality, together with the loss incurred when quality is not achieved. Juran, (1951, 1989) defined it as the sum of those costs that would vanish if there were no quality problems. While Juran (1951) established the COQ economic framework, Feigenbaum (1956) and Masser (1957) classified it in today's familiar categories of Prevention, Appraisal and Failure (PAF) costs. Prevention costs include the sum of all amounts spent or invested to prevent or at least significantly reduce errors or defects, in essence to finance activities aimed at eliminating the causes of possible defects and errors before they occur.

Table 3. 4: Causes of poor quality in construction
(Sources: Griffith 1990; Hammarlund and Josephson, 1991; Burati et al. 1992; Chung, 1999; Hwang et al., 2009; Love et al., 2004, 2010; Jafari and Love, 2013)

Causes of poor quality	**Design stage (examples)**	**Construction stage (examples)**
Design Changes	• Change made at request of the contractor • Change made by the client/clients representative to the design • Design revisions, modifications and improvements initiated by the architect, client/endusers, consultants, contractor/subcontractor • Result caused by the client changing the project definition, scope or requirements • External stakeholder changes	• A change in the method of construction in order to improve constructability • Changes in construction methods due to site conditions • Change made by the client/clients representative after some work has been performed on site • Contractor request to improve quality • Inadequate information during design stage e.g. site conditions. • Use of superceded drawings and specifications • Project definition, scope or requirements changed by client • External stakeholder changes
Errors and Omissions	• Incorrectly specified materials	• Defects in products • Erroneous construction methods procedures • Omissions of certain construction activities • Errors in transportation of wrong or defected materials
Poor Skills	• Inadequate knowledge/disregard for legislation or guidelines. • Inadequate coordination between client and designers • Poor interaction between client, designers and contractors • Inadequate supervision by designers • Lack of design empathy for construction • Failures in setting-out • Coordination failure • Poor quality documentation	• Defective workmanship • Insufficient work separation • Inadequate construction planning • Disturbances in personnel planning • Misinterpretation of drawings and specifications • Poor communication with the architect, engineer, subcontractors and material suppliers • Poor coordination of subcontracted work • Ambiguous instructions or unqualified operators / workers • Inadequate supervision and verification on site. • Poor detailing and workmanship • Poor quality documentation • Verbal/undocumented instructions by architect and engineers to contractor • Poor skills resulting in defective workmanship • Poor motivation levels of workforce

Appraisal costs include all amounts spent on the detection of errors or defects by measuring the conformity of different items to the required level or specifications of quality. Items include issued architectural and structural drawings, work in progress, incoming materials and finished products. Failure costs can be either internal or external. Internal failure costs are those incurred when rectifying an error or defect before a product leaves the construction organisation or while it is still under its control. Conversely, external failure costs are those incurred due to errors or defects in the product detected when the product has left the organisation or is no longer under its control (Aliverdi et al., 2013; Nabipoor et al., 2014).

Appraisal and prevention costs are unavoidable costs that must be borne by construction organisations if their products or services are to be delivered right the first time. Failure costs, on the other hand, are avoidable. By eliminating the causes of re-doing processes, substantial reductions in appraisal costs can also be achieved (Low and Hensen, 1998; Jafari and Love, 2013). Over time, COQ was broken down into two elements (1) the cost of good quality (COGQ) and (2) the cost of poor quality (COPQ). This has been elaborated by Beecroft (2000), Douglas (2012), Cosmin and Ana-Maria (2013). While COGQ constitutes prevention and appraisal costs, COPQ constitutes internal and external failure costs (See Figure 3.2). COGQ and COPQ can be referred to as the cost of conformance and the cost of non-conformance respectively (Crosby, 1979; 1996). The focus of the study is on COPQ due to the fact that they are unnecessary costs associated with rectifying quality failures.

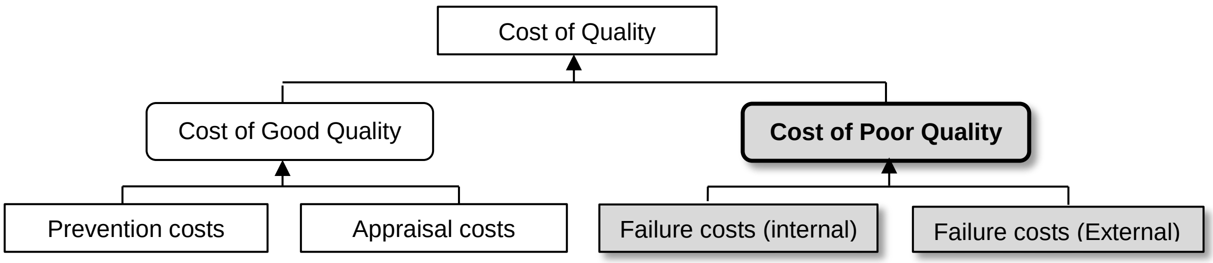


Figure 3. 2: Interrelationship between the COQ, COGQ and COPQ

According to Bland et al. (1998) COPQ is the difference between the actual operating cost and what the operating cost would have been if there were no failures in its systems and no mistakes by its staff. This can imply that poor quality comes from system failure, human error or incompetence. Campanella (1999) puts this as the difference between costs in the actual situation and costs in the ‘ideal’ situation, that is, in which no failures occur.

Similarly, Chiadamrong (2003) defined COPQ as the difference between the actual cost of a product or service and what the cost could be if the quality was perfect. It can therefore be deduced that COPQ is the cost of rectifying poor quality; the challenge therefore is to eliminate the causes of poor quality. Juran and Godfrey (1999) broke down COPQ into three components namely; cost of non-conformities, cost of inefficient processes and the cost of lost opportunities for sales revenue (See Figure 3.3). These categories were also highlighted by Atkinson et al. (1994), Dale and Plunkett (1995) and Sorqvist (1998) and Defeo and Juran (2010). According to Love et al (1998), COPQ is the total cost derived from problems occurring before and after a product or service is delivered.

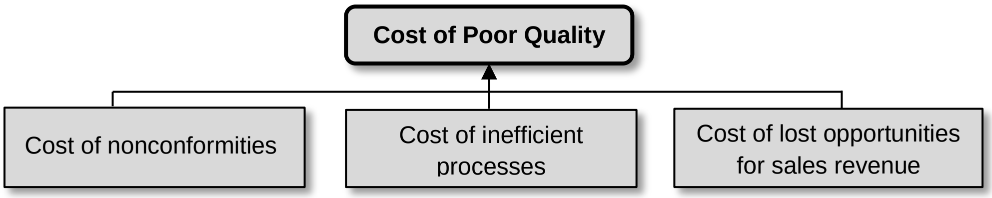


Figure 3. 3: Components of cost of poor quality
(Source: Juran and Godfrey, 1999; Defeo and Juran, 2010)

Costs associated with failure arise from both internal and external sources. Internal failure costs increase an organisational operations, for example, rework, material waste, and other avoidable process losses. However external failure costs results in loss of profit for example contractual claims, defects rectification and loss of future business. This means the cost of nonconformities and cost of inefficient processes relate to internal failure costs while the cost of lost opportunities for sales revenue relates to external failure costs.

There are other COPQ components that have been proposed by authors. Modarress and Ansari (1985) proposed two components namely the cost of quality design, and the cost of inefficient utilisation of resources. Sugiura (1997) proposed adjustment cost, and quality-design cost. According to Yang (2008) these new components have not been widely accepted by practitioners and researchers because the cost items entailed in these new categories are difficult to identify and quantify. There is also the ‘hidden quality cost’ component proposed by Chiadamrong (2003) as the costs of handling the quality problems that go beyond the visible costs of activities such as inspection, testing, rework, and improvement. The term ‘hidden’ or ‘invisible’ is used to indicate failure costs that are inadequately recorded or that are never actually discovered. Such hidden costs might be manifested as extra manufacturing costs as a result of defects or as additional costs for materials, machining time, and inventory space for scrapped and reworked parts (Dahlgaard et al., 1992). It can also occur as a result of a loss of goodwill or as a result of additional costs incurred in internal inefficiencies. While the proposed components are not widely used in academia and industry, what can be deduced is that there are tangible and intangible costs attached to poor quality. Tangible costs are easily quantifiable unlike intangible costs. This is true for all COPQ definitions and concepts from all authors.

3.4 AN INTEGRATED MODEL FOR THE COST OF POOR QUALITY

An integrated model for the cost of poor quality has been derived by synthesising the existing concepts on; the definition of quality (Crosby, 1979; Kano et al., 1984; Taguchi, 1993; ISO 9000: 2005; Ek and Çıkış, 2015), the causes of poor quality (Griffith 1990; Hammarlund and Josephson, 1991; Burati et al. 1992; Chung, 1999; Hwang et al., 2009; Love et al., 2004, 2010; Jafari and Love, 2013), the ‘PAF’ classification of the cost of poor quality (Feigenbaum,1956; Masser, 1957; Juran, 1989), and the components of the cost of poor quality (Juran and Godfrey, 1999; Defeo and Juran, 2010). The integrated concept is presented in Figure 3.4. The model shows the links between the various elements of the cost of poor quality. From the bottom up, errors and omissions, design changes and poor skills represent the contributory factors to poor quality. The effects of poor quality are usually threefold. They are: rework i.e. re-doing processes that should have been implemented correctly the first time; project delays; and wastage of resources (human and

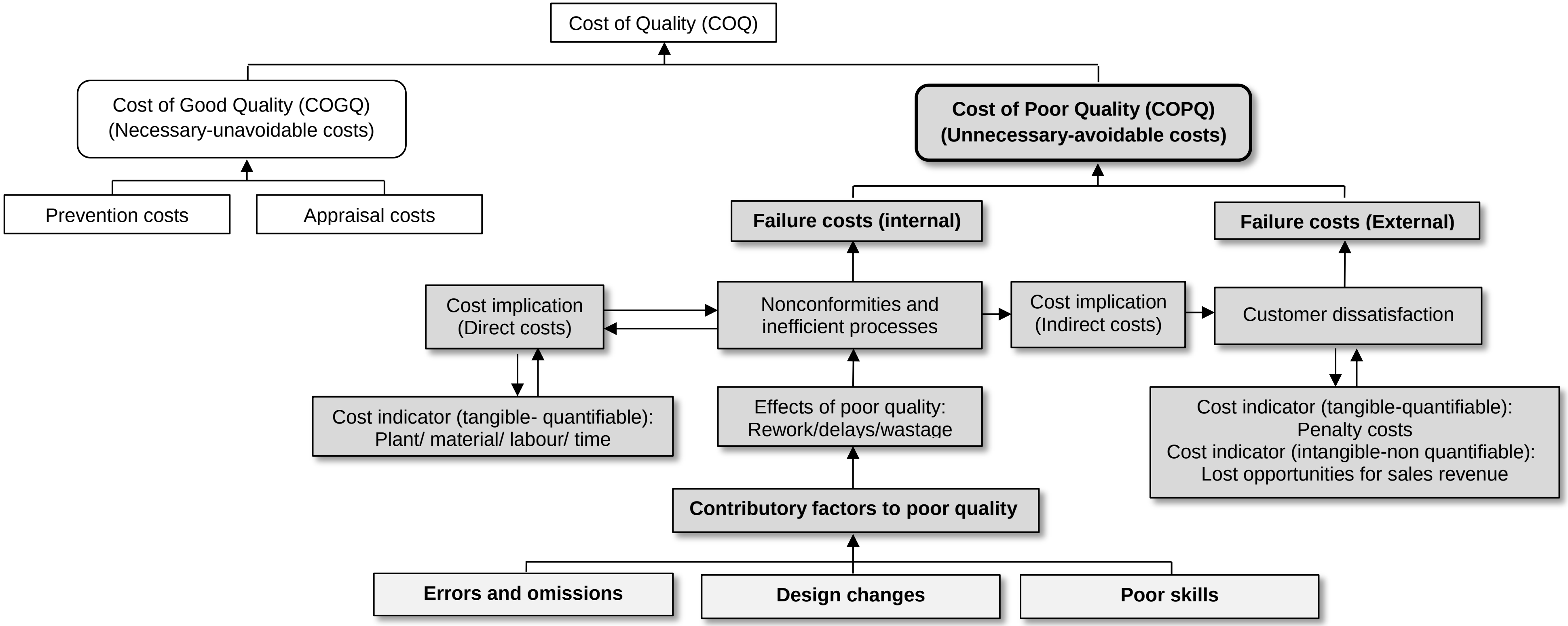


Figure 3. 4: An integrated model for the cost of poor quality on construction projects

material). The effects of poor quality are classified under nonconformities and inefficient processes which have direct and indirect cost implications.

Direct costs are tangible and quantifiable in terms of plant hire and usage, construction materials and products usage, labour (additional man hours), and time incurred to rectify issues. Indirect costs are associated with customer dissatisfaction. Indirect costs can be tangible and quantifiable in terms of penalty costs particularly to the contractor organisation. Indirect costs can also be intangible and non-quantifiable in terms of loss of goodwill from the customer (client) and lost opportunities for sales revenue. While nonconformities and inefficient processes contribute to internal failure costs, customer dissatisfaction contributes to external failure costs. Both internal and external failure costs add up to the cost of poor quality which is avoidable and unnecessary. The challenge therefore is to devise strategies to reduce errors and omissions, design changes and poor skills issues which ultimately lead to reduced cost of poor quality.

3.5 QUANTIFYING THE COST OF POOR QUALITY

Quantifying COPQ is crucial to the development of a quality plan consistent with an organisation's strategy. Estimates made as to the magnitude of quality costs in typical firms may explain the interest among researchers and practitioners. Chronologically, Crosby (1979) estimated that the COPQ amounts to 25–30% of turnover in manufacturing organisations and to 40–50% of direct operational costs in service organisations. Stephenson (1989) estimated the maximum as 15–20% of turnover regardless of business type. Researchers and practitioners have gone further to seek empirical evidence on COPQ. Empirical data sometimes reinforces estimates or theoretical calculations but sometimes disputes them. Virtanen (2000) found that COPQ calculated by organisations in averaged 3.9% of turnover. However, respondents estimated that the true costs, including costs not currently incorporated into figures, were on average 8.3% of turnover. This study however focuses on COPQ in construction and examines empirical evidence from previous research in the area. Research undertaken by Cnuddle (1991) determined failure costs in construction by investigating the amount of non-conformance that occurred on site. The cost of non-conformance was found to be between 10% and 20% of the total project cost furthermore it was found that 46% of total deviation costs were created during design, compared with 22% for construction deviations. Burati et al. (1992) collected data on quality deviations from 9 industrial engineering projects. It was found that 79% of total deviation costs were created during design compared with 17% for construction.

COPQ after the projects have been completed was as high as 4% of actual project cost out of which 51% was design-related, 26% was related to poor installation of materials and 10% to material failure. Abdul-Rahman (1995) found non-conformance costs excluding material wastage and head office overheads in a highway project to be 5% of contract value. Nylen (1996) found quality failures to be 10% of contract value on a railway project. Love and Li (2000) found rework costs in residential and industrial buildings to be 3.15% and 2.4% of contract value respectively. Researchers have attempted to find the mean value of costs. Love (2002) found the mean direct and indirect rework costs on 161 construction projects to be 6.4% and 5.6% of the original contract value respectively. Hwang (2009) obtained data from 359 construction projects and found direct rework costs alone to be 5% of total construction costs. Love et al. (2010) found the mean rework costs to be 10% of the contract value in 115 civil infrastructure projects studied. A sample of findings from previous studies on the cost of poor quality is shown in Table 3.5. It can be deduced from the findings that a substantial part of deviation costs are created during design (e.g. Cnuddle, 1991; Burati et al., 1992), in which case more attention need to be paid to design. According to Schneider (1997) 32% of errors can be detected through rigorous design checks. In addition, if an independent third party is used then as much as 55% of design errors could be accounted for.

Kvitrud *et al*., (2001) stated that while design checks and verifications are useful for identifying errors, their usefulness is restricted if lessons are not learnt from previous projects and appropriate training and skill development implemented. There is therefore a knowledge management aspect to quality management in reducing quality related costs. Although Abdul-Rahman (1995) made the point that non-conformance costs may be significantly higher in projects where poor quality management is implemented, Cox et al. (1999) found that the costs of design-related change orders affect contract value, even when projects are managed effectively, as most of the changes are initiated by clients. Love et al. (2010) also identified client change as one of the predictors for the cost of rework. This implies that the design change aspect of COPQ is inevitable as long as clients change their minds. Love et al. (2002), having examined 161 construction projects found that rework costs did not to vary significantly with project type and procurement method used. While this finding was presented by one author it is difficult to compare the finding with those of other authors.

Table 3. 5: A sample of the cost of poor quality on construction projects

Author	Areas of investigation	Cost of poor quality
Cnuddle(1991)	Non-conformance that occurred on site	Cost of non-conformance was between **10%** and **20%** of the total project cost. **46%** of total deviation costs were created during design, compared with **22%** for construction deviations
Burati et al. (1992)	Nine major engineering projects to determine the cost associated with correcting deviations to meet specified requirements	Quality deviations accounted for an average of **12.4%** of the contract value
Abdul-Rahman (1995)	Nonconformance costs excluding material wastage and head office overheads in a highway project	**5%** of the contract value
Nylen (1996)	Quality management practices in a railway project	Quality failures were found to be **10%** of the contract value
Cox et al. (1999)	Costs of design-related change orders in projects	Costs ranged from **5%** to **8%** of the contract value
Josephson and Hammarlund (1999)	Residential, industrial, and commercial building projects	Quality costs ranged from **2%** to **6%** of their contract values
Love and Li (2000)	Residential and industrial buildings	Costs of rework were found to be **3.15%** and **2.40%** of contract value respectively
Love (2002)	Data obtained from 161 construction projects	Mean direct and indirect rework costs were found to be **6.4%** and **5.6%** of the original contract value respectively
Hwang (2009)	Data obtained from 359 construction projects to assess the impact of different sources of rework on construction cost performance	Direct costs often tally to **5%** of total construction costs
Love et al. (2010)	Rework costs and probable causes were obtained from 115 civil infrastructure projects	Mean rework costs were found to be **10%** of the contract value

This is due to the fact that authors did not adopt the same methodology neither did they examine the same aspects of COPQ. The varying aspects examined include; quality failures (Nylen, 1996), non-conformance cost (Cnuddle, 1991), direct and indirect rework costs (Love, 2002; Love et al., 2010), design and construction related change orders (Cox et al., 1999; Borg and Song, 2015). While all these aspects relate to COPQ none of the authors adopted an integrated approach of examining all aspects of COPQ. The aspects include design changes, errors and omissions, poor skills, which lead to rework, delays and wastage, which are quantified in terms of plant, material, labour, time, and penalty costs. The challenge for researchers and industry practitioners therefore is to establish a unified methodology for quantifying COPQ which is a crucial step to formulating strategies for reducing it.

3.6 REDUCING THE COST OF POOR QUALITY

There exists a diverse range of initiatives and tools that are applicable for reducing the cost of poor quality, most of which originate from quality management in the manufacturing industry but have found application in the construction industry.

3.6.1 Initiatives for reducing the cost of poor quality

Crosby (1979) presented four absolutes to quality as follows: (1) quality is defined as adherence to requirements (2) prevention is the best way to ensure quality (3) ‘zero defects’ is the performance standard for quality (4) quality is measured by the price of non-conformity. Crosby (1979) presented fourteen steps to continuous quality improvement: (1) attain total commitment from management (2) form a quality improvement team (3) create metrics for each quality improvement activity (4) determine cost of quality and show how improvement will contribute to gains (5) train supervisors appropriately (6) encourage employees to fix defects and keep issues logs (7) create a zero-defects committee (8) ensure that employees and supervisors understand the steps to quality (9) demonstrate company's commitment by holding a zero defects day (10) set goals on 30, 60, or 90 day schedule (11) determine root causes of errors, remove them from processes (12) create incentives programs for employees (13) create a quality council and hold regular meetings (14) repeat from step one.

Deming (1985) presented the theory of Total Quality Management (TQM) which rests upon fourteen points of management: (1) create constancy of purpose (2) adopt the new philosophy (3) stop dependencies on mass inspections (4) do not award business based upon the price (5) aim for continuous production and service improvement (6) bring in cutting-edge on the job training (7) implement cutting-edge methods for leadership (8) abolish fear from the company (9) deconstruct departmental barriers (10) get rid of quantity-based work goals (11) get rid of quotas and standards (12) support pride of craftsmanship (13) ensure everyone is trained and educated (14) make sure the top management structure supports the previous thirteen points. A cycle was also created for continuous improvement known as Plan-Do-Check-Act (PDCA). Firstly in the planning phase, objectives and actions are outlined. Secondly, actions are 'done' or undertaken to implement the process improvements. Thirdly, checks are made to ensure quality against the original. Finally, acting requires determining where changes need to occur for continued improvement before returning to the plan phase.

Juran and Godfrey (1998) presented a methodology for quantifying and reducing COPQ in five steps: (1) quantify the size of the quality problem in a language that will have impact on upper management: the language of money improves communication between middle managers and upper managers (2) identify major opportunities for cost reductions: a major by-product of evaluation of cost is identification of costs of specific segments, each traceable to some specific cause (3) identify opportunities for reducing customer dissatisfaction and associated threats to product salability (or services): some costs of poor quality are the result of product failures which takes place after the sale. (4) provide a means of measuring the result of quality improvement activities instituted to achieve the opportunities in 2 and 3 above: measuring progress helps to keep a focus on improvement and also spotlights any lack of progress that requires removal of obstacles to improvement (5) align quality goals with organisation goals: measuring the cost of poor quality is one of the four key inputs for assessing the current status of quality. Knowing the cost of poor quality (and the other elements) leads to the development of a quality action plan consistent with overall strategic organisational goals. Deployment of strategic quality goals includes specific quality improvement and quality planning projects to pursue the opportunities in 2 and 3 above. These projects become the link between strategic goals and day-to-day quality activities.

ISO 9000 family of standards can also be utilised in reducing COPQ as they focus on quality management in organisations no matter what size or industry so that they become better managed, more efficient and more customer-focused. If well implemented, it results in 'cultural transition' to an atmosphere of continuous improvement. The ISO 9000 standard is a supplemental document that defines the vocabulary used in ISO 9001 and ISO 9004. The ISO 9001 standard is the core component of the ISO 9000 standards series: it contains the requirements for an organisation's quality management system (QMS). ISO 9004 contains optional guidelines to extend the benefits of ISO 9001 to a wider range of interested parties including society in general. ISO 9000 is based around eight quality management principles: (1) customer focus (2) leadership (3) involvement of people (4) process approach (5) system approach to management (6) continual improvement (7) factual approach to decision making (8) mutually beneficial supplier relationships.

The European Foundation for Quality Management (EFQM, 2010; Gašparík and Gašparíková, 2013) model is based upon nine criteria for quality management. There are five enablers (i.e. criteria covering the basis of how an organisation does things) and four results (i.e. criteria covering outcomes which are targeted, measured and achieved). The model refrains from prescribing any one methodology, but rather recognises the diversity in quality management methodologies. The nine criteria presented by the EFQM Model are: (1) Leadership: how leaders develop and facilitate the achievement of the mission and vision, create values required for long term success and implement these via appropriate actions and behaviours and are personally involved in ensuring that the organisation's management system is developed and implemented (2) Policy and strategy: how the organisation implements its mission and vision via a clear stakeholder focused strategy supported by relevant policies, plans, objectives, targets and processes (3) People: how the organisation manages, develops and releases the knowledge and full potential of its people at an individual, team-based and organisation-wide level and how these activities are planned in order to support its policy and strategy and the effective operation of its processes. (4) Partnerships and resources: How the organisation plans and manages its external partnerships and internal resources in order to support its policy and strategy and the effective operation of its processes. (5) Processes: how the organisation designs, manages and improves its processes to support the policy and strategy and fully satisfies and generates increasing value for its customers and other stakeholders. (6) Customer results: what the organisation is achieving in relation to its external customers. (7) People results: what the organisation is achieving in relation to its people. (8) Society results: what the organisation is achieving in relation to local, national and international society as appropriate. (9) Key performance results: what the organisation is achieving in relation to its planned performance.

Lean principles requires highly controlled processes operated in a well maintained and ordered environment that incorporates principles of employee-involved, system-wide, continual improvement. This involves five overriding principles: (1) Identify customers and specify value: only a small fraction of the total time and effort in any organisation actually adds value for the end customer. By clearly defining ‘value’ for a specific product or service from the end customer’s perspective, all the non-value activities or waste can be targeted and removed. (2) Identify and map the value stream: the value stream relates to the entire set of activities across all parts of the organisation involved in jointly delivering the product or service. This represents the end-to-end process that delivers the value to the customer. (3) Create flow by eliminating waste: eliminating waste ensures that products or services flow to the customer without any interruption, detour or waiting. (4) Respond to customer pull: involves understanding customer demands and creating processes to respond to this. So that only ‘what’ the customer wants is produced ‘when’ the customer wants it. (5) Pursue perfection: creating ‘flow’ and ‘pull’ requires radically reorganising individual process steps, but the gains become truly significant as the entire steps link together. As this happens more and more layers of waste become visible and the process continues towards the theoretical end point of perfection, where every asset and every action adds value for the end customer.

Six Sigma is utilised to improve the quality of process outputs by identifying and removing the causes of errors and minimising variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people or ‘champions’ within the organisation who are Six Sigma experts. Each Six Sigma project follows a defined sequence of steps and has quantified value targets such as; reduced process cycle time, reduced costs, increased customer satisfaction, and increased profits. The Six Sigma methodology consists of five phases represented by the acronym ‘DMAIC’ and described as: (1) Define the system, the voice of the customer, their requirements and the project goals specifically (2) Measure key aspects of the current process and collect relevant data (3) Analyse the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation. (4) Improve or optimise the current process based upon data analysis using techniques such as design of experiments to create a new, future state process. Set up pilot runs to establish process capability. (5) Control the future state process to ensure that any deviations from the target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process. While the DMAIC is used for projects aimed at improving an existing business process, a further methodology known by the acronym 'DMADV' is used for projects aimed at creating new product or process designs, and described as (1) Define design goals that are consistent with customer demands and the enterprise strategy (2) Measure and identify the characteristics that are critical to quality (CTQs), product capabilities, production process capability and risks (3) Analyse to develop and design alternatives (4) Design an improved alternative, best suited per analysis in the previous step (5) Verify the design, set up pilot runs, implement the production process and hand it over to the process owner.

It has been documented that a significant percentage of COPQ can be traced back to design (e.g. Cnuddle, 1991; Burati et al.,1992; Jafari and Love, 2013), more so the construction supply chains are constantly challenged to deliver successful projects despite tight budgets, limited manpower, accelerated schedules, and limited or conflicting information. There have been initiatives to reduce costs related to these aspects and to integrate the design and construction processes. A recent and prominent initiative in the construction industry is the Building Information Modelling (BIM) which is a digital representation of physical and functional characteristics of a facility (NBS, 2014). A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle i.e. from earliest conception to demolition. Though not a quality management initiative in its entirety, it incorporates quality management aspects such as ‘just-in-time’ production strategy that strives to improve a business' return on investment by reducing in-process inventory and associated carrying costs. It also incorporates aspects of knowledge management such as knowledge sharing among supply chain organisations and individuals. The model is expected to save time, reduce errors and reduce waste on site therefore leading to better value, quality and resultant customer satisfaction.

3.6.2 Quality management tools

There exists a variety of quality management tools available in the industry. Examples and brief description of the tools are shown in Table 3.6.

Table 3. 6: Examples of quality management tools and description

Quality management tools	Description
Benchmarking	A technique used to evaluate like processes or procedures for best and worst practices.
Cause and effect diagram (fishbone/ Ishikawa diagram)	Used to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation (Ishikawa, 1990). Causes are usually grouped into major categories to identify these sources of variation.
Check sheet/ concentration diagram	Simple document used for collecting data in real-time and at the location where the data is generated. The document is typically a blank form that is designed for the quick, easy, and efficient recording of the desired information, which can be either quantitative or qualitative. A check sheet is divided into regions, and marks made in different regions have different significance. Data is read by observing the location and number of marks on the sheet. Five basic types of check sheets are: (1) Classification: A trait such as a defect or failure mode must be classified into a category (2) Location: The physical location of a trait is indicated on a picture of a part or item being evaluated (3) Frequency: The presence or absence of a trait or combination of traits is indicated. Also number of occurrences of a trait on a part can be indicated. (4) Measurement Scale: A measurement scale is divided into intervals, and measurements are indicated by checking an appropriate interval (5) Check List: The items to be performed for a task are listed so that, as each is accomplished, it can be indicated as having been completed.
Control charts	These are tools used to determine whether or not a manufacturing or business process is in a state of statistical control. If analysis of the control chart indicates that the process is currently under control then data from the process can be used to predict the future performance of the process. If the chart indicates that the process being monitored is not in control, analysis of the chart can help determine the sources of variation, which can then be eliminated to bring the process back into control.
Decision criteria matrix	A matrix used for prioritising potential solutions using predetermined criteria that are scored based on their positive and negative contributions.
Failure modes and effect analysis	An analysis that identifies a specific root cause failure, the mode of failure, the effect of that failure, and the risk associated with its severity, occurrence and detectability.
KPI (Key Performance Indicator)	Metrics designed to track and encourage progress towards critical goals of the organisation. Strongly promoted KPIs can be extremely powerful drivers of behaviour, therefore it is important to carefully select KPIs that will drive desired behaviour.
Pareto Chart	A chart that ranks the problems or problem areas in order of relative importance helping to identify the critical few
Project Charter	A form of project agreement that includes critical information on the team, the nature of the problem proposed milestones, and the impact the project will have
Run Chart	Examines the pattern of data in time sequence to identify potential root causes due to certain natural grouping

3.7 ISSUES RELATING TO THE COST OF POOR QUALITY

There are issues relating to the cost of poor quality in construction which need to be addressed. One of such issues is that cost of poor quality is endemic and has been found to range from around 2% to over 10% of total project cost regardless of project type and size. Reducing the cost of poor quality can lead to significant savings due to the size of the construction industry. While attempts have been made by authors to quantify the cost of poor quality, none of them has adopted a holistic approach to quantifying it. Previous studies have focused on the constituent aspects of cost of poor quality instead, such as quality failures (e.g. Nylen, 1996), non-conformance costs (e.g. Abdul-Rahman, 1995), deviation costs (e.g. Cnuddle, 1991; Burati et al., 1992), direct and indirect rework costs (e.g. Love et al., 2002; Hwang, 2009), design and construction related change orders (e.g. Cox et al., 1999; Love et al., 2010).

While all these aspects relate to the cost of poor quality, none of the authors adopted an integrated approach in quantifying all the aspects. The aspects include errors and omissions, design changes, and poor skills, which lead to rework, delays and wastage, which are then quantified in terms of plant, material, labour, time, and penalty costs (Golob et al., 2013; Nabipoor et al.,2014. There is therefore no unified methodology for quantifying the cost of poor quality neither is there a unified terminology in describing the aspects of the cost of poor quality. This creates difficulty in comparing ‘like-for-like’ performance from project to project, which is a crucial step to formulating strategies for benchmarking and continuous improvement. There exists the critical need to formulate strategies for reducing the cost of poor quality on construction projects not only because government reports have criticised the industry for underperforming but because clients are becoming more sophisticated, insisting on better value for money, and demanding more units of construction for fewer units of expenditure.

Table 3. 7: Issue relating to the cost of poor quality on construction projects

Issues relating to COPQ
• COPQ is endemic and has been found to range from 2% to over 10% of total project cost. This is very significant due to the size of the construction industry. • While attempts have been made to quantify COPQ, there has been no unified methodology in quantifying it thereby making 'like-for-like' comparisons of projects difficult • There are no unified terminologies describing aspects of COPQ • There exists a critical need to formulate strategies for reducing COPQ due to government and client demands

3.8 SUMMARY OF CHAPTER 3

This chapter examined the existing body of work on quality management with a specific focus on the cost of poor quality on construction projects. It discussed the conceptualisations of quality including key definitions and applications. It reviewed and presented findings from three case studies obtained from a secondary source which deal with construction stakeholders' influence on the definition of quality on construction projects. It was found that quality is not just defined by the customer (construction client) but is also influenced by external stakeholders. The causes of poor quality were found to be errors and omissions, design changes and poor skills. The cost of poor quality was found to constitute the cost of non-conformities, cost of inefficient processes and the cost of lost opportunity for revenue. It was discovered that the cost of poor quality is endemic and is found to be over 10% of total project costs in certain cases. The chapter explored quality management initiatives and tools used by organisations in reducing the costs of poor quality. It also identified the issues relating to COPQ in construction project management.

CHAPTER 4

CONCEPTUAL FRAMEWORK

This chapter synthesises the body of work on knowledge management and the cost of poor quality. It examines the links between knowledge management and the prevalent cost of poor quality on construction projects. It identifies the issues, challenges, knowledge gaps and key research questions on the impact of knowledge management in reducing the cost of poor quality. It presents the key research questions together with a matrix showing the areas of inquiry. It distinguishes between a theoretical framework and a conceptual framework. It also presents an initial conceptual framework for the study which is subject to modifications at later stages of the study.

4.1 SYNTHESISING KM AND COPQ

The rationale for undertaking the research was driven by the need to reduce COPQ on construction projects. While COPQ may be regarded as a quality management problem, the study takes a novel approach by exploring the link between KM and COPQ. This chapter focuses on integrating the concepts of KM and COPQ in order to develop a conceptual framework on the impact of KM in reducing COPQ. Although none of the previous studies have investigated the impact of KM on COPQ nor shown any empirical evidence on the extent of the impact, literature suggests that poor KM contributes to COPQ and that optimising KM can reduce COPQ thereby leading to improved project performance, increased profitability, increased customer satisfaction and improved industry reputation. Before developing the framework, it is fundamental to summarise the followings:

- Findings from literature review on KM and COPQ
- Issues and challenges relating to KM and COPQ
- Knowledge gaps
- Key research questions to be addressed.

4.1.1 Findings from literature review on KM and COPQ

The first objective of the research is to critically review existing literature in the area of KM from both general and construction industry perspectives in order to explore, identify and document the key concepts, processes, tools, KM drivers, enablers, benefits, barriers and issues relating to KM and the possible link to COPQ. The second objective is to critically review existing literature in the area of quality management with a specific focus on COPQ in construction, in order to explore, identify and document the key concepts of quality, the causes of poor quality, the costs associated with poor quality, the quality management initiatives for reducing COPQ, the issues relating to COPQ in construction and the possible link to KM. The details of the first and second objectives have been discussed in the previous two chapters. The key findings however are summarised as follows:

- KM is invaluable to the construction industry as it is deemed critical for construction organisations to harness and integrate knowledge in order to improve efficiency and increase profitability.
- Despite KM initiatives, construction projects are still plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to additional project costs.

- A major area of focus is on the cost attached to the unnecessary effort of re-doing processes or activities incorrectly implemented the first time often referred to as the cost of poor quality. This includes the cost of errors and omissions, cost of design changes, cost of poor skills and the consequential costs associated with client dissatisfaction
- COPQ is endemic and has been found to range from around 2% to over 10% of total project cost regardless of project type and size
- Previous studies have focused on the constituent aspects of COPQ such as quality failures, non-conformance cost, direct and indirect rework costs, design and construction related change orders. None of the studies have attempted a holistic approach of integrating all these aspects which include design changes, errors and omissions, poor skills which lead to rework, delays and wastage, and quantified in terms of plant, material, labour, time, and penalty costs.
- Previous studies have also adopted different methodologies in quantifying aspects of COPQ, which makes it difficult to compare COPQ from project to project and to benchmark progress in the industry.
- Government reports have criticised the industry for underperforming. Clients are becoming more sophisticated, insisting on better value for money, and demanding more units of construction for fewer units of expenditure. There exists therefore the critical need to formulate strategies for reducing the COPQ in construction.
- Furthermore no research has been found to date that has investigated the impact of KM in reducing COPQ on construction projects.

4.1.2 Issues and challenges relating to KM and COPQ

- The construction industry is project-based thereby posing the challenge of knowledge capture, retention and re-use
- The industry is fragmented thereby brings about the challenge of knowledge integration across organisations
- The industry is criticized for being poor at learning, 'reinventing the wheel', repeating mistakes and wasting resources
- Multiple organisations are typically involved in a single project creating the challenge of integration and collaborative working with a focus on the end product and customer value
- Clients are often dissatisfied with project performance, project process and product quality
- There is low profitability of organisations as a result of KM related inefficiencies
- Larger organisations are more likely to formally practice KM than the majority of small organisations
- COPQ is endemic and may be difficult to quantify, especially the intangible aspects of external failure costs.
- There exists a critical need to formulate strategies for reducing COPQ due to government and client demands

In addition, the current trends in the UK construction industry is presented in the Industry Performance Report (2014) based on the Construction Industry Key Performance Indicators. This showed that industry profitability has fallen to just 2.1% continuing the trend of decline that took hold during the depression of

2008/09. Project costs were on budget or better for 69% of projects. Contractor satisfaction with the client's provision of information fell back during 2013/14 from a survey high recorded previously. Design costs came in on or under budget 79% of the time. Predictability in the cost of construction was broadly unchanged with 57% coming in on budget or better compared to 58% in 2012 and 59% in 2011. Projects as a whole were completed to, or ahead of schedule 45% of the time. This is in line with the survey average since 2003. The design was delivered on time or better for 52% of all projects, but smaller projects outperformed larger ones. The construction phase was on time or better for 67% of projects.

4.1.3 Knowledge gaps

Knowledge gaps refer to the missing element(s) in previous research literature that is intended to be filled by the current research. They also indicate findings from previous research in which key questions have not been answered. According to Sarewitz (1996) knowledge gaps can be perceived in four ways (1) as a barrier on the linear path towards complete understanding (2) as contingent on the changeable social and cultural processes which drive the production of scientific knowledge (3) as a lack of sufficient integration of knowledge from different sources and disciplines; and (4) as a space where a thickening of knowledge can occur through the addition of new layers of meaning and significance to understandings of reality. All these ways of understanding knowledge gaps are present in the current study on the impact of KM in reducing COPQ which are summarised as follows:

- Attempts have been made by authors to quantify COPQ, but none of them has adopted a holistic approach in its quantification. Instead, previous studies have focused on the constituent aspects of COPQ. This research intends to bridge the knowledge gap by integrating all the aspects and presenting a holistic model to quantifying COPQ.
- Much of the research in the area of KM take an organisational perspective and relatively little attention have been given to the impact of KM exploitation on construction projects. These studies typically focus on ways of managing the knowledge resources and capabilities of an organisation through the use of KM processes and tools with the overall aim of gaining competitive advantage over potential competitors. KM however needs to advance beyond organisational level through the utilisation of a more robust approach in developing a push-pull strategy for knowledge integration across personal, organisational, project and industry interfaces in order to retain existing knowledge and to create new knowledge. This key aspect is missing in the existing body of work on KM.
- While KM and COPQ may be viewed as two distinct areas in practice, evidence suggests a link between the two. However none of the existing body of work has examined the interconnectedness of KM and COPQ. Furthermore no research has been found to date that has investigated the impact of KM on COPQ neither have there been any framework or tools developed to measure the impact.

4.1.4 Key research questions to be addressed

The research questions identified were based on the research problem and the knowledge gap the research intends to bridge. The main research questions for this study are stated as follows:

(1) What are the contributory factors to the cost of poor quality on construction projects in practice?

(2) What is the impact of knowledge management in reducing the cost of poor quality based on the identified contributory factors?

(3) How can knowledge management be optimised to reduce the cost of poor quality on construction projects?

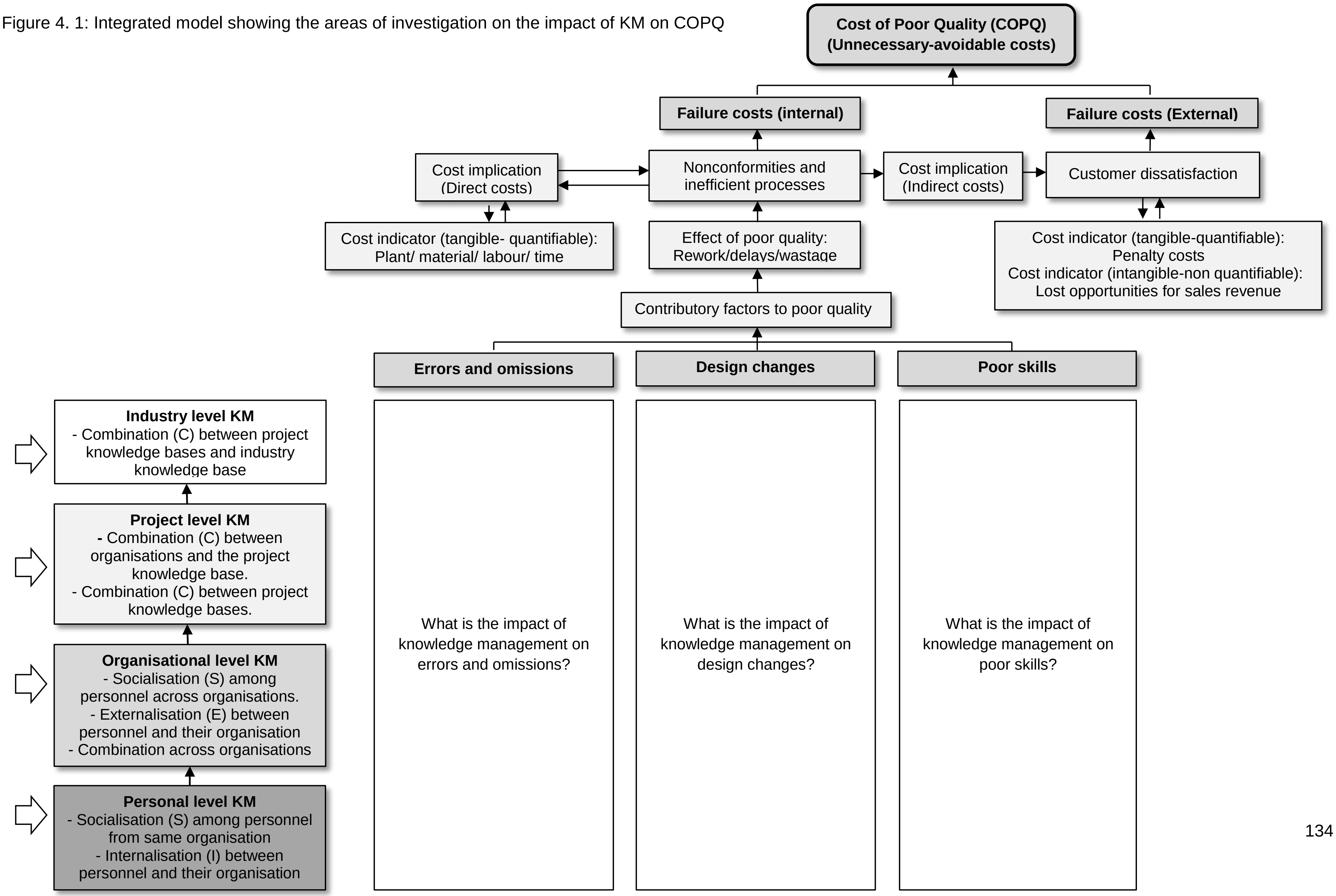
The first research question investigates the contributory factors to COPQ in practice. While the key elements to COPQ have been identified through literature review as the costs of errors and omissions, the cost of design changes and the cost of poor skills, it is unclear if there are more of these elements and it the findings from literature can be localised in the current UK construction industry context. The research therefore seeks to investigate these elements in practice and also identify the contributory factors to each element. The second research question explores the impact of KM in reducing COPQ based on the contributory factors identified in practice. This helps to identify the current KM initiatives and practices at personal, organisational, project and industry levels and their impact in reducing unnecessary costs associated with poor quality in construction. The research question also investigates KM processes and tools utilised by organisations to reduce COPQ. The third research question investigates the optimisation of KM to reduce COPQ. This question investigates the impediments and facilitators of KM, together with the actions required to make the best and the most effective use of KM in reducing COPQ on construction projects.

The three research questions follow a logical sequence in which the first investigates the underlying causes of the research problem. While the second question investigates the current impact of KM on COPQ (i.e. how does KM impact COPQ?), the third question investigates the potential impact of KM on COPQ (i.e. how should KM impact COPQ?). The aim of the research therefore is to bridge the gap between the current impact and potential impact i.e. raising KM performance from its current level to an optimised level to reduce COPQ. An integrated KM-COPQ model is presented in Figure 4.1 which shows the areas of investigation on the impact of KM on COPQ. The integrated model combines the SECI application model (Figure 2.10, Chapter 2) with the COPQ model (Figure 3.4, Chapter 3) which forms a template for investigation.

4.2 SETTING IMPACT MEASURES

A key aim of the research is to investigate the impact of KM in reducing COPQ (Figure 4.1). The key questions to be asked therefore are: What is impact? How is impact measured? Impact can be defined as a marked effect or influence of one phenomenon on the other. It is a measure of consequences of one thing's or entity's action over another. Impact can be direct or indirect, positive or negative, tangible or intangible, short term or long term. Impact can be measured by creating indicators to measure and track the outcomes of impact. For any outcome, there is a range of possible signs, symptoms or hints by which these outcomes can be observed, measured or detected with varying

Figure 4. 1: Integrated model showing the areas of investigation on the impact of KM on COPQ



degrees of certainty. Indicators can be either quantitative or qualitative (Oyewobi et al., 2015).

While Qualitative indicators help to demonstrate, describe or measure that something has happened, quantitative indicators help to answer questions about things that are inherently expressed in numbers. Both are considered for this research. It is important to select indicators of performance, quality, or outcomes that are within the organisation’s scope to measure and use. Four criteria for choosing indicators (Walker et al., 2000; Mayoux, 2002; Jackson 2004) are:

(1) Action focused: Does knowing about this issue help the organisation or its key stakeholders to do things better or more effectively? Is it within the organisation’s power to influence it?

(2) Important: Is it relevant to the organisation? Is it a priority for a core stakeholder or group of stakeholders?

(3) Measurable: Can information be obtained and measured?

(4) Simple: Is it clear and direct enough to be understood by all stakeholders? Is it easy enough to get information without expert assistance if none is available?

The integrated concept is presented in Figure 3.4. The model shows the links between the various elements of the COPQ. From the bottom up, errors and omissions, design changes and poor skills represent the contributory factors to poor quality. The effects of poor quality are usually threefold. They are: rework i.e. re-doing processes that should have been implemented correctly the first time; project delays; and wastage of resources (human and material). The effects of poor quality are classified under nonconformities and inefficient processes which have direct and indirect cost implications. Direct costs are tangible and quantifiable in terms of plant hire and usage, construction materials and products usage, labour (additional man hours), and time incurred to rectify issues. Indirect costs are associated with customer dissatisfaction. Indirect costs can be tangible and quantifiable in terms of penalty costs particularly to the contractor organisation. Indirect costs can also be intangible and non-quantifiable in terms of loss of goodwill from the customer (client) and lost opportunities for sales revenue. While nonconformities and inefficient processes contribute to internal failure costs, customer dissatisfaction contributes to external failure costs. Both internal and external failure costs add up to the cost of poor quality which is avoidable and unnecessary.

4.3 CONCEPTUAL FRAMEWORK

A conceptual framework is the system of concepts, assumptions, expectations, beliefs, and theories that supports and informs research and is a key part of research design (Miles and Huberman, 1994; Robson, 2011). Miles and Huberman (1994) defined a conceptual framework as a visual or written product, one that explains, either graphically or in narrative form, the main items to be studied, the key factors, concepts, or variables and the presumed relationships among them.

4.3.1 Theory, concept and framework

Before proceeding to the conceptual framework design, it is important to define and clarify the terms ‘theory’, ‘concept’, and ‘framework’ within the context of the research. Fox and Bayat (2007) defined theory as a set of interrelated propositions, concepts and definitions that present a systematic point of view of specifying relationships between variables with a view to predicting and explaining phenomena. In a similar way Liehr and Smith (1999) defined theory as a set of interrelated concepts, which structure a systematic view of phenomena for the purpose of explaining or predicting. A theory is similar to a blueprint or a guide for modelling a structure. Blueprint depicts the elements of a structure and the relation of each element to the other, just as a theory depicts the concepts, which compose it and the relation of concepts with each other. Furthermore, Liehr and Smith (1999) made a connection between theory and practice such that theory guides practice while practice enables testing of theory and generates questions for research. Research therefore contributes to theory-building and selecting practice guidelines.

Chinn and Kramer (1999) described theory as an expression of knowledge, a creative and rigorous structuring of ideas that project a tentative, purposeful, and systematic view of phenomena. According to Wacker (1998), theory has four components namely: definition of terms, concepts or variables; a domain to which the theory is applicable; a set of relationships amongst the variables; and specific predictive claims. Putting all these elements together, a theory is therefore a careful outline of the precise definitions in a specific domain to explain why and how the relationships are logically tied so that the theory gives specific predictions. Thus, a good theory is taken to be one which gives a very clear and precise picture of events of the domain it seeks to explain. Therefore a theory’s precision and limitations are founded in the definitions of terms, the domain of the theory, the explanation of relationships, and the specific predictions.

A concept can be defined as an image or symbolic representation of an abstract idea (Liehr and Smit, 1999), or as the component of theory which conveys the abstract ideas within a theory (Chinn and Kramer, 1999). A concept is also viewed as a complex mental formulation of experience in which case, meanings and interpretations are largely influenced by their context. Concepts can be of real or 'concrete' phenomena (e.g. buildings) and can also be of agreed-upon or 'abstract' phenomena (e.g. quality). According to Thompson (2006) three classes of things can be measured: direct observables such as height, weight, or colour; indirect observables such as questionnaires that provide information on gender, age or income; and constructs which are theoretical creations that are based on observations but which cannot be seen either directly or indirectly such as IQ, leisure satisfaction, or environmental values. Lehman et al., (2005) further described conceptualisation as the process of specifying what is meant by a term. In deductive research conceptualisation helps to translate portions of an abstract theory into testable hypothesis involving specific variables. In inductive research, conceptualisation is an important part of the process used to make sense of related observations.

Framework in research has been defined as a structure that provides guidance for the researcher as research questions are fine-tuned, methods for measuring variables are selected, and analyses are planned (Liehr and Smith, 1999). Once data is collected and analysed, the framework is used as a tool to check whether the findings agree with the framework or whether there are discrepancies. Where discrepancies exist, a further question is asked whether or not the framework can be used to explain them. In the context of this research, a framework can act as a guide in explaining and interpreting the impact of knowledge management in reducing the cost of poor quality in construction with respective levels of academic integrity and acceptability. Furthermore, a framework is a broad overview, outline, or skeleton of interlinked items which supports a particular approach to a specific objective, and serves as a guide that can be modified as required by adding or deleting items (Fox and Bayat, 2007).

4.3.2 Theoretical framework versus conceptual framework

A theoretical framework refers to the theory adopted by researchers to guide research. A theoretical framework therefore is the application of a theory, or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or shed light on a particular phenomenon or research problem. This could refer to, for instance, the Set theory, evolution, quantum mechanics, particulate theory of matter, or similar pre-existing generalisation such as Newton’s laws of motion, gas laws, that could be applied to a given research problem deductively. On the other hand, if a research problem cannot meaningfully be researched in reference to only one theory, or concepts resident within one theory, the researcher may have to synthesise the existing views in the literature concerning a given situation both from theoretical and empirical findings. The synthesis may be called a ‘model’ or conceptual framework, which essentially represents an integrated way of looking at the problem (Liehr and Smith 1999). Such a model could then be used in place of a theoretical framework.

A conceptual framework can therefore be defined as an end result of integrating a number of related concepts to explain or predict a given event, or give a broader understanding of the phenomenon of interest or research problem. The process of arriving at a conceptual framework is similar to an inductive process whereby small individual concepts are joined together to tell a bigger map of possible relationships. Thus, a conceptual framework is derived from concepts just as a theoretical framework is derived from a theory. Schematically, this can be represented as shown in Figure 4.2. Whereas a whole theory may serve as a theoretical framework, a conceptual framework is normally of limited scope carefully put together in the form of a conceptual model, and immediately applicable to a particular study.

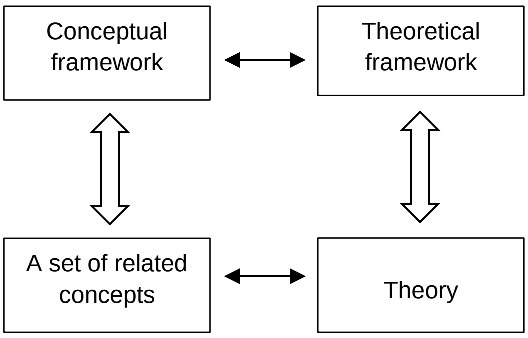


Figure 4. 2: Derivation of conceptual and theoretical frameworks

Both conceptual and theoretical frameworks represent an integrated understanding of issues within a given field of study, which enables the researcher to address a specific research problem. These theoretical perspectives guide the individual researcher in terms of specific research questions, hypotheses or objectives leading to a better directed review of literature, the selection of appropriate research methods, and the interpretation of results. A number of researchers can work on the same research problem, using different theoretical or conceptual frameworks, and each arriving at legitimate findings. In deductive research, researchers normally use a dominant theory to address a given research problem, while in inductive research, many aspects of different theoretical perspectives are brought together to build up a generalisation with enough ‘power’ to guide the study (Liehr and Smith 1999). Induction moves from the particular to the general, from a set of specific observations to the discovery of a pattern that represents some degree of order among all the given events (de Vos et al. 2005). According to Borgatti (1999), theoretical frameworks are obviously critical in deductive or theory-testing sorts of studies. Hence, in attempting to distinguish between theoretical and conceptual framework, it can be deduced that; while research based on deductive reasoning makes use of a pre-existing theory, or theoretical framework, research based of inductive reasoning tends to be theory-building.

Both conceptual and theoretical frameworks refer to the epistemological paradigm a researcher utilises to examine a given research problem. However, the scope of conceptual frameworks is usually applicable only to the specific research problem for which it was created. Application to other research problems may be limited. Since theoretical frameworks refer to the application of theories, they tend to have a much wider scope of use beyond one research problem. Table 4.1 summarises the key differences between theoretical and conceptual frameworks. These differences are embedded in their genesis, conceptual meanings, how they each relate to the process of literature review, the methodological approaches they evoke and their scope of application. Once a conceptual framework has been established, the purpose is largely similar to that of a theoretical framework. However, where a conceptual framework 'shapes up' from a synthesis of existing literature and freshly collected data, such a conceptual framework tends to serve as a springboard for further research. The findings from an initial research can therefore lead to an articulation of a theory from which a theoretical framework can therefore evolve.

Table 4. 1: A summary of the differences between conceptual and theoretical frameworks

Variable	**Theoretical framework**	**Conceptual framework**
Genesis	• Evolves or 'takes shape' from reviewed literature and/or data collected. • Adopted/adapted from a pre-existing theory or theoretical perspective	• Created by the researcher from a variety of conceptual or theoretical perspectives
Purpose	• Helps the researcher see clearly the main variables and concepts in a given study. • Provides the researcher with a general approach (methodology, research design, target population and research sample, data collection and analysis • Guides the researcher in the collection, interpretations and explanation of the data.	• Helps the researcher see clearly the main variables and concepts in a given study. • Provides the researcher with a general approach (methodology, research design, target population and research sample, data collection and analysis) • Guides the researcher in the collection, interpretation and explanation of the data no dominant theoretical perspective exists • Guides future research specifically where the conceptual framework integrates literature and field data
Conceptual meaning	• Application of a theory as a whole or in part.	• Synthesis of relevant concepts
Process underlying review of literature	• Mainly deductive, as in natural sciences where hypothesis testing takes place to verify the 'power' of theory	• Mainly inductive, as in social sciences where research problems cannot ordinarily be explained by one theoretical perspective. • Some social science research also gets driven by theories, but theories in the social sciences tend not to have the same 'power' as those in the natural sciences.
Methodological approach	• Located mainly in the quantitative research paradigm. • Data collected mainly through experimental designs, empirical surveys and tests • Efforts made to standardise context or else ignore it.	• May be located in both quantitative and qualitative research paradigms increasingly mixed method research approaches are recommended • Data mostly collected through empirical and descriptive survey instruments, interviews and direct observations hence a preponderance of qualitative data • Strong on consideration of context
Scope of application	• Wider application beyond the current research problem and context.	• Limited to specific research problem and/or context

Having examined the key differences between a theoretical framework and a conceptual framework it is evident that a conceptual framework is more appropriate than a theoretical framework for the purpose of this research. The research therefore adopts the use of a conceptual framework to investigate the impact of knowledge management in reducing the cost of poor quality in construction. It is also important to note that this research process commences with an inductive approach (qualitative method) followed by a deductive approach (quantitative method). The main difference between inductive and deductive approaches to research is that while a deductive approach is aimed at testing theory, an inductive approach is concerned with the generation of new theory emerging from data.

A deductive approach usually begins with a hypothesis while an inductive approach will usually use research questions to narrow the scope of the study. For deductive approaches the emphasis is generally on causality while for inductive approaches the aim is usually focused on exploring new phenomena or examining previously researched phenomena from a different perspective. While inductive approaches are generally associated with qualitative research and a conceptual framework, deductive approaches are more commonly associated with quantitative research and a theoretical framework. Although this research adopts mixed method approach, utilising a conceptual framework is deemed appropriate particularly as the research commences with qualitative method.

4.4 DESIGN OF THE CONCEPTUAL FRAMEWORK FOR THE STUDY

The conceptual framework (Figure 4.3) consists of 7 components which are labelled from [A] to [G]. The conceptual framework has been developed as an output from the critical review of literature on KM and COPQ.

Component [A] forms the core of the study which stems from findings from literature that COPQ is prevalent on projects regardless of project type and size. It was also rooted in the findings that construction projects are still plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to additional project costs. The study therefore suggests that there is a link between KM and COPQ. This is reflected in this component of the conceptual framework. The component suggests through arrow diagrams that: (1) poor KM leads to prevalent COPQ, which appears to be the current status quo (2) optimised KM leads to reduced COPQ. The challenge therefore is to explore how KM can be optimised to reduce COPQ i.e. bridging the gap between poor KM and optimised KM to reduce COPQ.

Component [B] shows the KM levels identified from literature review namely; personal, organisational, project and industry. KM entails harnessing and integrating knowledge across the interfaces of the four levels. Component [C] shows the contributory factors to COPQ identified from literature review namely; errors and omissions, design changes, and poor skills. These three factors were found to contribute to the internal failure cost element of COPQ. Since external failure costs results from internal failure costs, the conceptual idea therefore is that reducing internal failure cost automatically reduces external failure costs.

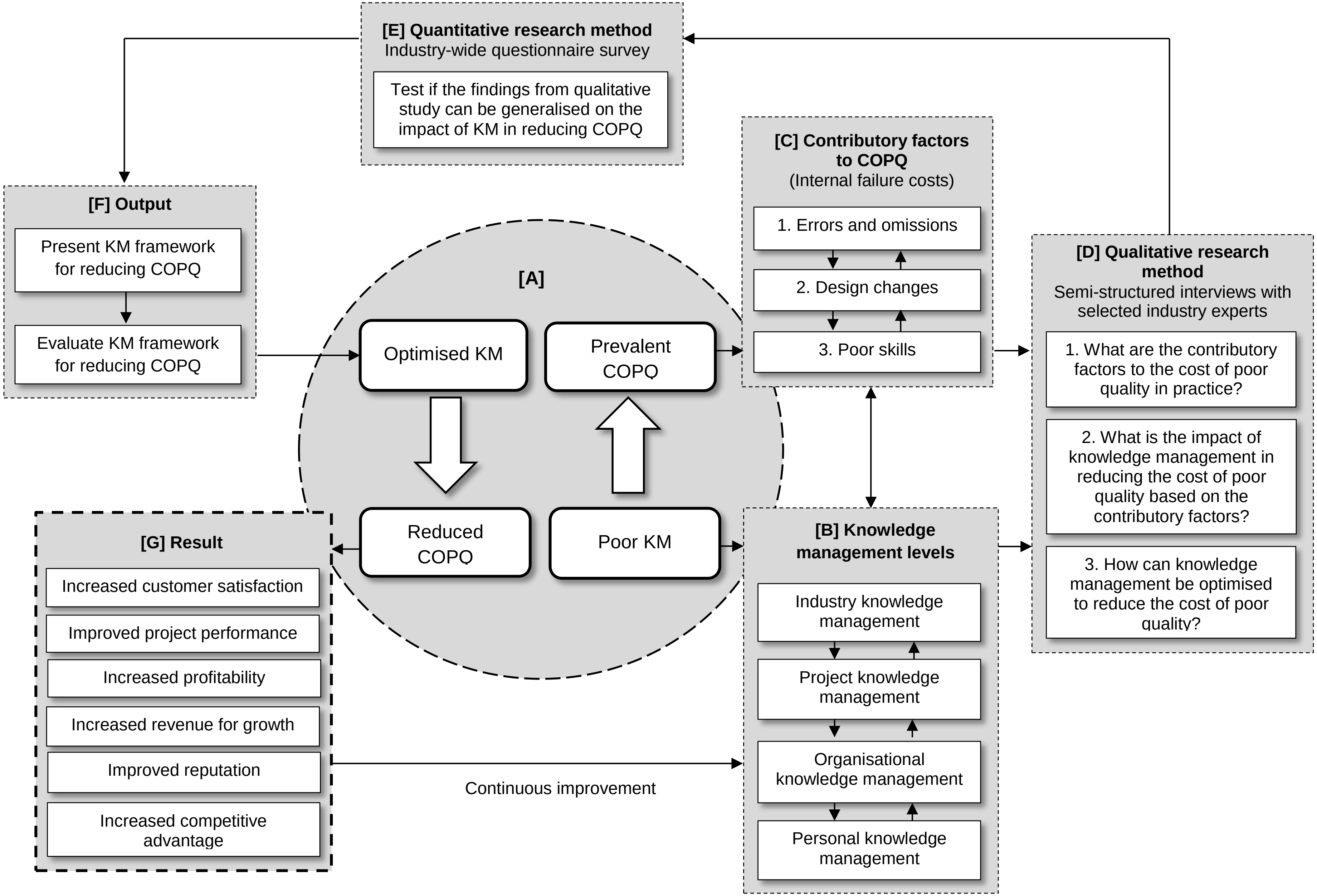

[E] Quantitative research method
Industry-wide questionnaire survey
Test if the findings from qualitative study can be generalised on the impact of KM in reducing COPQ
[F] Output
Present KM framework for reducing COPQ
Evaluate KM framework for reducing COPQ
[A]
Optimised KM
Prevalent COPQ
Reduced COPQ
Poor KM
[C] Contributory factors to COPQ
(Internal failure costs)
1. Errors and omissions
2. Design changes
3. Poor skills
[D] Qualitative research method
Semi-structured interviews with selected industry experts
1. What are the contributory factors to the cost of poor quality in practice?
2. What is the impact of knowledge management in reducing the cost of poor quality based on the contributory factors?
3. How can knowledge management be optimised to reduce the cost of poor quality?
[G] Result
Increased customer satisfaction
Improved project performance
Increased profitability
Increased revenue for growth
Improved reputation
Increased competitive advantage
[B] Knowledge management levels
Industry knowledge management
Project knowledge management
Organisational knowledge management
Personal knowledge management
Continuous improvement

Figure 4. 3: Initial conceptual framework on the impact of KM on COPQ

The focus of study was therefore based on reducing internal failure costs. Component [D] connects components [B] and [C] through qualitative research to investigate the impact of [B] on [C]. This involves semi-structured interviews with selected industry experts to investigate the impact of KM on COPQ. This component is derived from the key research questions to be addressed which are stated as follows: (1) What are the contributory factors to the cost of poor quality in practice? (2) What is the impact of knowledge management in reducing the cost of poor quality based on the contributory factors? (3) How can knowledge management be optimised to reduce the cost of poor quality? There are also follow-on questions attached to the key questions. The output from component [D] leads to the modification of the conceptual framework, and the generation of propositions, hypothesis or further research questions on the impact of KM in reducing COPQ.

Component [E] tests the output from component [D] through an industry-wide questionnaire survey across the UK, the output of which leads to component [F] i.e. the development of a KM framework for reducing COPQ. Component [F] presents and validates the framework. The purpose of the framework is to present a holistic approach to optimising KM to reduce COPQ as shown in component [A] with measureable results shown in Component [G]. The results include increased customer satisfaction, improved project performance, increased profitability, increased revenue for growth, improved industry reputation and increased competitive advantage for organisations in the supply chain. The conceptual framework can be 'fine-tuned' through continuous improvement in other to constantly find ways to further reduce COPQ. The conceptual framework is expected to evolve as the study progresses.

4.5 SUMMARY OF CHAPTER 4

This chapter synthesised the body of work on knowledge management and the cost of poor quality. It examined the links between knowledge management and the prevalent cost of poor quality on construction projects. It identified the issues, challenges, knowledge gaps and key research questions on the impact of knowledge management in reducing the cost of poor quality. One of the knowledge gaps is that no research has been found to date that has investigated the impact of knowledge management on the cost of poor quality in construction. While the cost of poor quality may be regarded as a quality management problem the study takes a different approach of exploring the link between knowledge management and the cost of poor quality. This contributes to the novelty of the research. The chapter presented the key research questions together with a matrix showing the areas of inquiry. The research questions posed were: (1) what are the contributory factors to the cost of poor quality in practice? (2) What is the impact of knowledge management in reducing the cost of poor quality based on the contributory factors? (3) How can knowledge management be optimised to reduce the cost of poor quality? The chapter distinguished between a theoretical framework and a conceptual framework. It also presented an initial conceptual framework for the study which is subject to modifications at later stages of the study.

CHAPTER 5

RESEARCH METHODOLOGY

This chapter discusses the methodology used for the research. It provides an overview of the methodological process comprising of literature review, conceptual framework, the research approach and the validation of framework. It examines different research approaches and their underlying philosophical assumptions. It explores different research designs or strategies of inquiry available for research including methods for data collection and analysis. It discusses the selection and justification of the research approach, research design and research methods for this study. The chapter also discusses the sampling strategies and ethical issues considered for the research.

5.1 OVERVIEW OF RESEARCH METHODOLOGY

Research methodology has been defined as the principles underlying the methods by which research can be carried out (Creswell, 2007; Fellows and Liu, 2008). It is a general approach to which research is undertaken (Silverman, 2008). Research methodology thus covers the entire process of a study. It demonstrates how research can be carried out and how data can be gathered and analysed to achieve its aims and objectives. It refers to the principles and procedures of logical thought processes, which are applied to a scientific investigation (Fellows and Liu, 2008). The methodology for this study includes literature review, conceptual framework, research approach, research methods of data collection and analysis, validation of framework and conclusion. The literature review aspect of this study examined the critical points of current body of work in the areas of knowledge management and the cost of poor quality.

According to Marshall and Rossman (2006), literature review accomplishes several purposes including gaining insight into previous work being done in the area whilst also filling the gaps or extending prior studies. Information sources for the literature review included printed journals, online gateways and databases, online journals, reference texts, conference papers and various books in the context of the topic. Some of the sources used for literature review include; Architectural Engineering and Design Management (AEDM), Journal of Construction Engineering and Management, Quality Management Journal, Construction Management and Economics (CME), American Society for Quality (ASQ), International Journal of Productivity and Quality Management, Journal of Quality Management, International Journal of Project Management (IJPM), Engineering, Construction and Architectural Management (ECAM), Journal of Information and Knowledge Management, Journal of Knowledge Management.

Other sources include industry reports from organisations such as; the Commission for Architecture and the Built Environment (CABE), National Audit Office, Office of National Statistics, Department for Business Innovation and Skills, Office of Government Commerce, Constructing Excellence and Glenigan. The output from literature review was used to develop the conceptual framework which integrates knowledge management with the cost of poor quality and sets the direction for data collection, analysis and validation. The literature review and outputs have been covered in chapters 2 and 3; the conceptual framework was covered in chapter 4;

the research approach including research methods of data collection and analysis is covered in the current chapter.

5.2 RESEARCH APPROACHES

Research approaches systematically describe the activities to be undertaken in order to achieve the research aims and objectives. According to Creswell (2014), research approaches are plans and procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis and interpretation. This involves several decisions which are informed by: (1) the philosophical assumptions brought to the study by the researcher, (2) the procedures of inquiry or research designs, and (3) specific research methods of data collection, analysis and interpretation (Punch, 1999; Fellows and Liu, 2003; Neuman, 2006; Creswell, 2014). The selection of a research approach is based on the nature of the research problem or issue being addressed. It is also based on the researcher's personal experiences as well as the audiences for the study. According to Creswell (2014) there are three types of research approaches: (1) Qualitative research approach (2) Quantitative research approach (3) Mixed methods approach.

5.2.1 Qualitative research approach

Qualitative research approach deals with the procedure for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. It involves emerging questions and procedures in which data is typically collected in the participant's setting, with data analysis inductively building from particular to general themes, and the researcher making interpretations of the meaning of the data (Creswell, 2013). In other words qualitative research is based on text rather than numbers. Moreover, Kaplan and Maxwell (1994) argued that it is essential to understand the informant's point of view and the particular social and institutional context at play and such is not possible when textual data are quantified. Maxwell (1998) further argued that the strengths of qualitative research are founded on its inductive process, focus on specific situations or people, and emphasis on words rather than numbers.

5.2.1.1 Philosophical assumptions underlying a qualitative approach

Constructivism or social constructivism, often referred to as interpretivism, underlies a qualitative approach to research (Berger and Luekmann, 1967; Lincoln and Guba, 1985; Crotty, 1998; Mertens, 2010). One of the philosophical assumptions is that humans construct meanings as they engage with the world they are interpreting. Qualitative researchers therefore tend to use open-ended questions so that the participants can share their views. Another assumption is that humans engage with their world and make sense of it based on their historical and social perspectives. Thus, qualitative researchers seek to understand the context or setting of the participants through visiting this context and gathering information personally. They also interpret what they find, an interpretation shaped by the researcher's own experiences and background.

The basic generation of meaning is always social, arising in and out of interaction with a human community. The process of qualitative research is largely inductive; the inquirer generates meaning from the data collected in the field. Further to the constructivist worldview is the transformative worldview which holds that research inquiry needs to be intertwined with politics and a political change agenda to confront social oppression at whatever levels it occurs (McTaggart, 2000; Neuman, 2009; Mertens, 2009, 2010). Thus, the research contains an action agenda for reform that may change lives of the participants, the institutions in which individuals work or live, and the researcher’s life. Moreover, specific issues need to be addressed that speak to important social issues of the day, issues such as empowerment, inequality, oppression, domination, suppression, and alienation. The transformative worldview or paradigm places central importance on the study of lives and experiences of diverse groups that have traditionally been marginalised. Of special interest for these diverse groups is how their lives have been constrained by oppressors and the strategies that they use to resist, challenge, and subvert these constraints. In studying these diverse groups, the research focuses on inequities based on gender, race, ethnicity, disability, sexual orientation, and socioeconomic class that result in asymmetric power relationships. The research in the transformative worldview links political and social action to these inequities. Transformative research uses a program theory of beliefs about how a program works and why the problems of oppression, domination, and power relationships exist.

5.2.1.2 Research designs for qualitative approach

There are different research designs available for different research aims. Creswell (2013) identified five qualitative research designs which encompass a continuum from narrow to broad focus. These research designs were classified as; narrative, ethnography, phenomenology, case study and grounded theory. Narrative research involves the study of lives and experiences of individuals which are retold as chronological narratives. A narrative typically focuses on gathering data from stories and discussing the meaning of the experiences in them. Examples of narratives include biographies and autobiographies. Some advocates of narrative research (e.g. Clandinin and Connelly, 2000; Garson, 2008) assert that it is an empowering social science approach insofar as it affords respondents the opportunity to articulate their view points.

Ethnography research relates to the study of an intact cultural group in a natural setting over prolonged period of time, using mainly observation methods (Creswell, 2013). Ethnography is considered one of the most in-depth research methods possible as long involvement of the researcher affords the opportunity to observe not only what people say they do but what they actually do (LeCompte and Schensul, 1999). It is a flexible research process and typically evolves contextually in response to the realities encountered in the field setting (Walcott, 2008; Fetterman 2010).

Phenomenological research involves the study of ways a person’s world is formed in part by the person who lives it (Fischer and Wertz, 2002). It is therefore concerned with the ‘lived experiences’ of people regarding a phenomenon of interest and requires the researcher to ‘bracket’ taken-for-granted assumptions and unusual ways of perceiving the phenomenon. The emphasis often is to describe personal perspectives and interpretations rather than to explain them. Phenomenology typically involves conducting interviews (Moustakas, 1994; Giorgi, 2009)

Case study encompasses the holistic, in-depth study of a phenomenon typically using a variety of data sources and procedures (Stake, 1995; Yin, 2009). Case studies are most useful when the boundaries between phenomenon and context are not clearly evident. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time (Stake, 1995; Yin, 2009, 2012). Yin (2012) provided a useful treatise on design and implementation of case study research.

Grounded theory is a systematic process of generating theory that explains, at a broad conceptual level, process, an action or interaction about a substantive topic, grounded in the views of the participants in the study (Creswell, 2008). This often involves multiple stages of data collection, constant refinement of findings and the continuous search for interrelationships among emerging categories of information (Corbin and Strauss, 2008). Grounded research often requires theoretical sampling in which the emerging patterns of information dictate subsequent information requirements and hence research sites or cases.

5.2.1.3 Research methods for qualitative approach

Data is usually collected in the field at the site where participants experience the issue or problem under study. This up close information, gathered by actually talking directly to people and seeing them behave and act within their context, is a major characteristic of qualitative method. Data is typically collected by the researcher through examining documents, observing behaviour or interviewing participants. The data is reviewed and organised into categories or themes that cut across all of the data sources. This involves building their patterns, categories and themes from the bottom up by organising the data into increasingly more abstract units of information. This inductive process illustrates working back and forth between themes and the database until a comprehensive set of themes is established by the researcher. The entire qualitative research process is focused on learning the meaning that the participants hold about the problem or issue not the meaning that the researchers bring to the research or writers express in literature. The research process for qualitative research is ‘emergent’ i.e. the initial plan for research cannot tightly be prescribed and all phases of the process may change or shift during and after data collection.

5.2.2 Quantitative research approach

Quantitative research approach involves the procedure for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically on instruments, so that numerical data can be analysed using statistical procedures (Creswell, 2014). The approach deals with research problems by using mathematical and statistical techniques to identify facts and causal relationships. It therefore adheres to the practices and norms of the natural scientific model (Fitzgerald and Howcroft, 1998; Naoum, 2007). Quantitative research approach is therefore deductive in nature as it focuses on developing theories or hypotheses, operationalising concepts and subjecting them to rigorous empirical testing.

5.2.2.1 Philosophical assumptions underlying quantitative approach

The post-positivist assumptions have represented the traditional form of research, and these assumptions hold true more for quantitative research than qualitative research. This worldview is sometimes called the scientific method, or doing science research. It is also called positivist research or empirical research. The term ‘post--positivism’ is preferred for use in this study because it represents the thinking after positivism, challenging the traditional notion of the absolute truth of knowledge (Phillips and Burbules, 2000; Creswell, 2014) and recognising researchers cannot be positive about claims of knowledge when studying the behaviour and actions of humans. In a post-positive worldview, knowledge is conjectural and antifoundational i.e. absolute truth can never be found. Thus, evidence established in research is always imperfect and fallible. It is for this reason that researchers state that they do not prove a hypothesis; instead, they indicate a failure to reject the hypothesis (Phillips and Burbules, 2000). Research, in this case, is the process of making claims and then refining or abandoning some of them for other claims more strongly warranted. Most quantitative research, for example, start with the test of a theory where data, evidence, and rational considerations shape knowledge.

5.2.2.2 Research designs for quantitative approach

Quantitative research designs can be classified into experimental and non-experimental (surveys). Experiments are further classified into true or classical experiments and quasi-experiments. Experimental research involves the postulation of a priori hypotheses, which are then tested empirically. The true or classical experiment derives its logic from manipulating, comparing, and looking for differences among, subjects. Thus, it is also known as ‘the method of difference’. The main focus is to create causal relationships between the independent and the dependent variables. By manipulating the incidence of the independent variable and controlling the effects of the extraneous variables, causal relationships are developed to explain the phenomenon. To satisfy requirements for internal validity, it is important to ensure that control and experimental groups are equivalent. This is achieved through random sampling or the use of systematic controls.

Quasi-experiments, while regarded as unscientific and unreliable by pure scientists, the method is nevertheless useful in social sciences particularly in measuring social variables. The inherent weaknesses in the methodology do not undermine the validity of the data, as long as they are recognised and allowed for during the whole experimental process. Quasi-experimental design involves selecting groups, upon which a variable is tested, without any random pre-selection processes.

Non-experimental (surveys) designs are those in which standardised questionnaire is designed and administered to measure the thoughts, attitudes, feelings or behaviours of a sample drawn from a population. However, the choice and design of a survey instrument will generally depend on the aims of the research, that is, whether it is: analytic, where it investigates causal relationships between phenomena; descriptive, where it assesses the attributes of a population of subjects, or exploratory, where it tests grounded theory using structured questionnaire as part of the study plan (Gill and Johnson, 1997).

5.2.2.3 Research methods for quantitative approach

The experimental method is usually taken to be the most scientific of all methods, perhaps because the non-experimental method lack control over situation. The experimental method therefore is a means of trying to overcome this problem. An experimental method studies cause and effect. It differs from the non-experimental method in that it involves the deliberate manipulation of one variable, while trying to keep all other variables constant. Experiments can be carried out in the laboratory, on the field or in natural environments. In the case of surveys, a typical survey method can indicate whether the survey will be cross-sectional with the data collected at one point in time of whether it will be longitudinal with data collected over time; specify form of data collection. Survey methods can take several forms which include a written document (questionnaire) in which the respondent self-completes or a document administered face-to-face or through a telephone interview by the researcher. The data collected may also involve creating a web-based or internet survey and administering it online (Nesbary, 2000; Sue and Ritter, 2007). Surveys are, however prone to three main flaws (Mitchell and Jolley, 2001): researcher not knowing what he or she wants; poor construct validity of measures; and poor external validity when biased samples are used. These flaws however can be mitigated thoughtful planning and design of surveys. In this regard several authors (e.g. Fowler, 2002; Scheuren, 2004; Czaja and Blair, 2005; Dillman, 2007) provide useful guidance.

5.2.3 Mixed methods approach

Although most researchers utilise either quantitative or qualitative approaches in their work, it is becoming commonplace to combine both methods in a single study. The combination of the two approaches is known as mixed methods approach (Creswell and Piano Clark, 2011). The core assumption is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone.

5.2.3.1 Philosophical assumptions underlying mixed methods approach

Mixed methods approach stems from a pragmatist worldview which arises out of actions, situations, and consequences rather than antecedent conditions as in post-positivism (Patton, 1990; Cherryholmes, 1992). Instead of focusing on methods, researchers emphasise the research problem and use all approaches available to understand the problem (Rossman and Wilson, 1985). As a philosophical underpinning for mixed methods approach, Morgan (2007), Patton (1990), and Tashakkori and Teddlie (2010) convey its importance for focusing attention on the research problem and then using pluralistic approaches to derive knowledge about the problem. Pragmatism therefore is not committed to any one system of philosophy and reality neither does it see the world as an absolute unity. Thus, for the mixed approach to research, pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis.

5.2.3.2 Research designs for mixed methods approach

There are different variations or sub-types of mixed methods used in research, three of which are regarded as primary (Creswell and Piano Clark, 2011; Creswell, 2008, 2014). They are: convergent parallel mixed methods; explanatory sequential mixed methods; and exploratory sequential mixed methods.

Convergent parallel mixed method is a form of mixed methods design in which the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem. In this design, the investigator typically collects both forms of data at roughly the same time and then integrates the information in the interpretation of the overall results. Contradictions or incongruent findings are explained or further probed in this design.

Explanatory sequential mixed method is that in which the researcher first conducts quantitative research, analyses the results and then builds on the results to explain them in more detail with qualitative research. It is considered explanatory because the initial quantitative data results are explained further with the qualitative data. It is considered sequential because the initial quantitative phase is followed by the qualitative phase. This type of design is popular in fields with a strong quantitative orientation, but it presents challenges of identifying the quantitative results to further explore and the unequal sample sizes for each phase of the study.

Exploratory sequential mixed method is the reverse sequence from the explanatory sequential design. In the exploratory sequential approach the researcher first begins with a qualitative research phase and explores the views of participants. The data are then analysed, and the information used to build into a second, quantitative phase. The qualitative phase may be used to build an instrument that best fits the sample under study, to identify appropriate instruments to use in the follow-up quantitative phase, or to specify variables that need to go into a follow-up quantitative study. The above three basic designs can then be used in more advanced mixed methods designs such as transformative mixed method, embedded mixed method, and multiphase mixed method.

5.2.3.3 Research methods for mixed approach

Mixed research method involves collecting both qualitative and quantitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks. Data can be collected concurrently or sequentially and only the data is integrated at one or more stages in the process of the research (Teddlie and Tashakkori, 2010). This approach can also be used to reduce or eliminate disadvantages of each individual approach while gaining the advantages of each and of the combination (Fellows and Liu, 2008). Researchers often use the terms ‘mixed methods’, ‘multi-methods’ and ‘triangulation’ synonymously, however the terms have differences in meaning. According to Morse (2003), a multi-method design is different from a mixed method research in the sense that is involves qualitative and quantitative projects that are relatively

Table 5. 1: Summary of research approaches
(Sources: Creswell and Piano Clark, 2013, Creswell, 2014)

	Qualitative approach	**Quantitative approach**	**Mixed methods approach**
Philosophical assumptions	• Constructivist/transformative knowledge claims	• Post-positivist knowledge claims	• Pragmatic knowledge claims
Research design	• Phenomenology, grounded theory, ethnography, case study and narrative	• Surveys and experiments	• Sequential, concurrent, and transformative
Research methods	• Open-ended questions, emerging approaches, text or image data	• Closed-ended questions, instrument based questions, predetermined approaches	• Both open and closed ended questions, both emerging and predetermined approaches
Research instruments	• E.g. interview template	• E.g. survey questionnaire	• E.g. interview template/survey questionnaire
Research practices	• Collects participant meanings • Focus on a single concept or phenomenon • Brings personal values into the study • Studies the context or setting of participants • Validates the accuracy of findings • Makes interpretations of the data • Creates an agenda for change or reform • Collaborates with the participants	• Tests or verifies theories or explanations • Identifies variables to study • Relates variables in questions or hypotheses • Uses standards of validity and reliability • Observes and measures information numerically • Uses unbiased approaches • Employs statistical procedures	• Collects both quantitative and qualitative data • Develops a rationale for mixing • Integrates the data at different stages of inquiry • Presents visual pictures of the procedures in the study • Employs the practices of both qualitative and quantitative research

complete on their own and then used together to form essential components of one research program. Thus each study is planned and conducted to answer a particular sub-question, and the results of the research triangulated to form a comprehensive whole. Mixed methods utilises various combinations of data collection methods associated with both qualitative and quantitative research. Qualitative data tends to be open-ended without predetermined responses while quantitative data usually includes closed-ended responses such as found on questionnaires.

5.3 SELECTION OF RESEARCH APPROACH FOR THIS STUDY

The research approach for this study situates within the methodological process shown in Figure 5.1. The process constitutes three phases: (1) theoretical work (2) fieldwork (3) evaluation and conclusion. The theoretical work covers objectives 1 – 3 of the study and chapters 1 – 5 of the thesis. Chapters 1 – 4 have already been discussed. The current chapter discusses the research methodology, particularly the selection of research approach which forms the basis for Phase 2 (fieldwork) of the study. Phase 2 discusses the fieldwork in details covering objectives 4 and 5 of the study and chapters 6 – 7 of the thesis. Phase 3 discusses the evaluation and conclusion of the study which covers objectives 6 and 7 of the study and chapters 8 – 9 of the thesis. Having critically examined the three types of research approaches (qualitative, quantitative and mixed methods), mixed method approach was selected for the study. This is due to the inductive and deductive nature of the research problem. The details of the rationale for selecting a mixed method approach are discussed in Sections 5.3.1, 5.3.2 and 5.3.3.

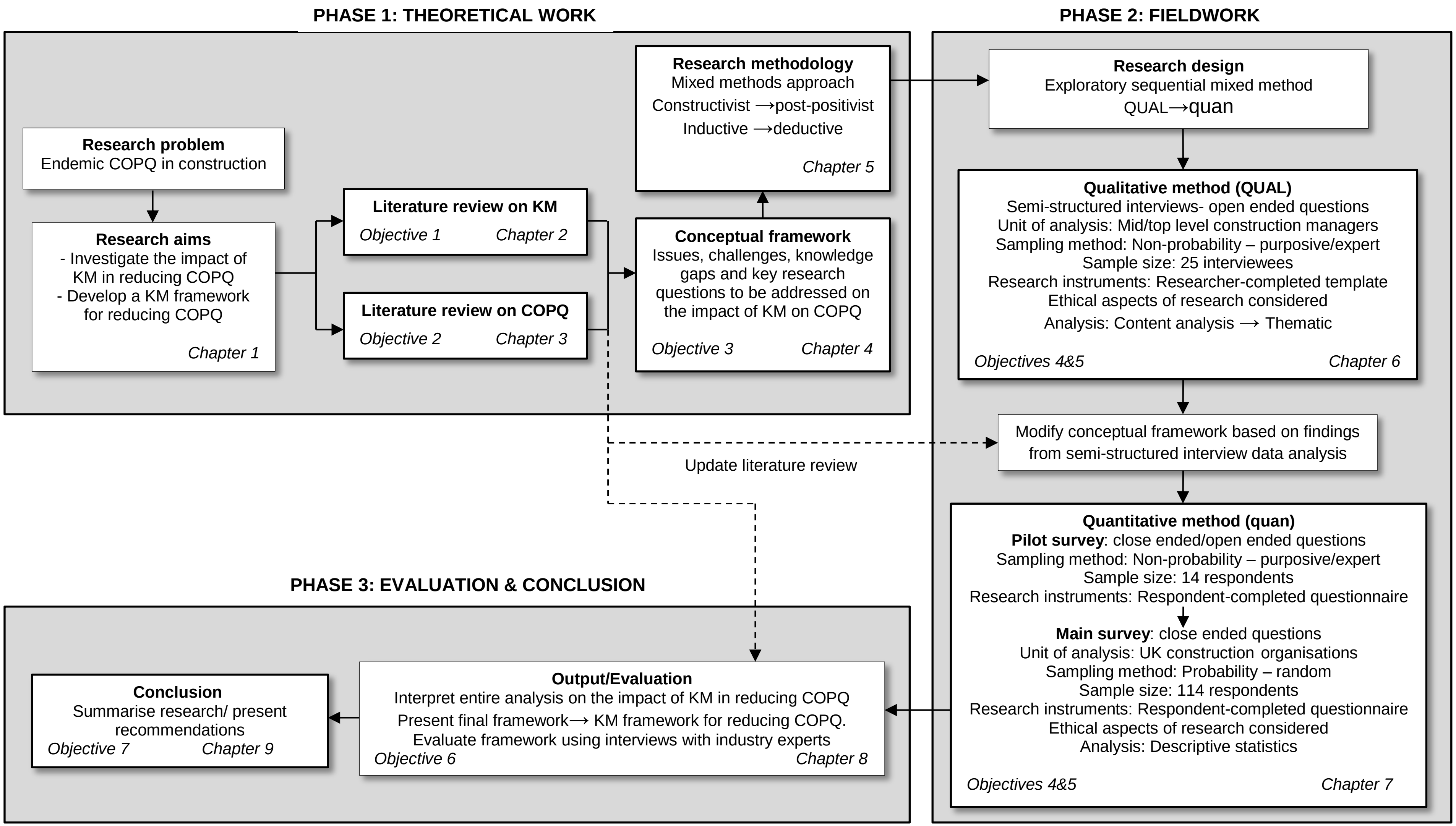


Figure 5. 1: Overview of the methodological process for the research

According to Newman and Benz (1998), quantitative and qualitative strategies should not be viewed as rigid, distinct categories, polar opposites or dichotomies; instead they represent different ends on a continuum. A study can tend to be more qualitative than quantitative or vice versa. A mixed method approach therefore resides in the middle of this continuum because it incorporates elements of both qualitative and quantitative strategies.

5.3.1 Philosophical assumptions underlying the study

The selection of mixed methods approach for this study was based on the researcher's pragmatic worldview which arises out of actions, situations, and consequences rather than antecedent conditions encountered in post-positivist view. The researcher holds the view that all available approaches must be utilised to understand a research problem. As a philosophical underpinning for mixed methods studies, Patton (1990), Morgan (2007), and Tashakkori and Teddlie (2010) convey the importance of pragmatism in addressing a research problem. Pragmatism is not committed to any one system of philosophy and reality, thus applies to mixed methods research by drawing liberally from both quantitative and qualitative assumptions.

However it is important to note that not all situations justify the use of mixed method approach. There are times when qualitative approach may be best and other times when quantitative approach may be best. The most significant determinant for selecting a research approach is the nature of the research problem itself. Creswell (2008) identified the categories of research problems suited for mixed methods approach as those in which: (1) one data source may be insufficient (2) results need to be explained (3) exploratory findings need to be generalised (4) a second method is needed to enhance a primary method (5) a theoretical stance need to be employed (6) an overall research objective can be best addressed with multiple phases, or projects. This research situates within the third category because the need exists to generalise exploratory findings on the impact of KM in reducing COPQ on construction projects.

In this case, it is fundamental to explore qualitatively to learn what questions, variables, theories, and so forth need to be studied and then follow up with a quantitative study to generalise and test what was learned from the exploration. The main research questions in this study are exploratory in nature e.g. what are the contributory factors to the cost of poor quality on construction projects? What is the impact of knowledge management in reducing the cost of poor quality? How can knowledge management be optimised to reduce the cost of poor quality? There are also several follow-on questions such as ‘why….?’, or ‘how…?’ These are open-ended exploratory questions requiring a qualitative approach and then followed up with a quantitative approach to test whether the qualitative findings can be generalised.

5.3.2 Selection of research design for the study

The research designs considered for this study were: convergent parallel mixed methods; explanatory sequential mixed methods; exploratory sequential mixed methods; transformative mixed methods, embedded mixed methods; and multi-phase mixed methods. These mixed methods were discussed sub-section 5.2.3.2. Due to the nature of the research problem and the research questions to be addressed on the impact of KM in reducing COPQ on construction projects, exploratory sequential mixed methods was considered most suitable to address the questions. In this design, the qualitative phase was used; firstly to build an instrument that best fits the sample under study, secondly to identify the appropriate research instruments for the follow-up quantitative phase, and thirdly to specify variables that need to go into the quantitative study. Mixed method designs are often described using notations which provides shorthand labels and symbols that convey important aspects of mixed methods research (Creswell, 2008; Tashakkori and Teddlie, 2010). The notation for exploratory sequential mixed method is shown in Figure 5.2. ‘QUAL’ (in upper case) represents qualitative method as a major element of the mixed methods while ‘quan’ (in lower case) represents the follow-up or supporting quantitative methods

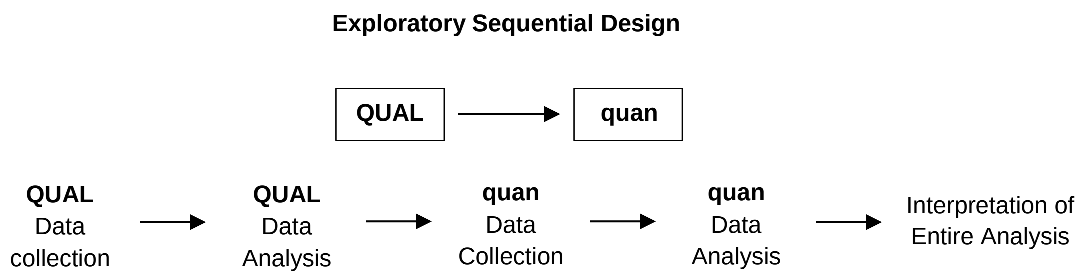


Figure 5.2: Notation for exploratory sequential mixed method design (Source: Creswell, 2008)

5.3.3 Selection of research methods for the study

In accordance with the choice of research approach and research design, the study utilises mixed methods for data collection, analysis and interpretation. The selection of mixed methods for this study capitalises on the strengths of both qualitative and quantitative methods while offsetting both of their weaknesses.

The main features and the key differences between qualitative and quantitative methods are summarised in Table 5.2 while the strengths and weaknesses of each are summarised in Table 5.3. Having examined the key features and the strengths and weaknesses of both methods, the pros and cons of combining both methods are summarised in Table 5.4.

Table 5. 2: The differences between quantitative and qualitative research
(Sources: Creswell, 2008, 2014)

Criteria	Qualitative	Quantitative
Literature review	May be done as study progresses	Must be done early in the study
Theory	Develops theory	Tests theory
Reality	• Multiple realities: focus is complex and broad • Discovery, description, understanding, shared interpretation	• One reality i.e. focus is concise and narrow • Reduction, control, precision • Measurable
Process	Report rich narrative, individual interpretation; basic element of analysis is word or idea • Researcher is part of process • Context dependent • Research questions • Reasoning is dialectic and inductive • Describes meaning, discovery • Uses communication and observation • Strives for uniqueness	Report statistical analysis, basic element of analysis is number • Researcher is separate • Context free • Hypotheses • Reasoning is logistic and deductive • Establishes relationships, causation • Uses instruments • Strives for generalisation • Designs: descriptive, correlation
Sample size	Sample size is not a concern; seeks 'information rich' sample	30 to 500
Research control	Poor at controlling rival factors and hypotheses	Good at controlling rival factors and hypotheses
Relationship	Cannot examine and test covariance, interaction, size and direction of effects	Can examine and test covariance, interaction, size and direction of effects
Concepts	• Relies on empathetic connection with subjects • Not replicable because of flexibility, lack of structure and impossibility of replicating contexts	• Much attention paid to concept, their operationalisation and measurement • Replicable
Information orientation	Process oriented i.e. want information on how things happen, how results are produced	Outcome oriented i.e. want information on what the outcome or end results are
Nature of problem	• Exploratory research • Variables unknown • Context important • May lack theory base for study	• Previously studied by other researchers so that body of literature exists • Known variables • Existing theories

Table 5. 3: Strengths and weaknesses of qualitative and quantitative methods
(Sources: Creswell, 2008; Tashakkori and Teddlie, 2010; Denzin and Lincoln, 2011; Creswell and Piano Clark, 2013)

	Qualitative methods	**Quantitative methods**
Strengths	• Data is based on the participants' own categories of meaning • Useful for studying a limited number of cases in depth • Provides individual case information • Can conduct cross-case comparisons and analysis • Provides understanding and description of people's personal experiences of phenomena • Can describe in rich detail phenomena as they are situated and embedded in local contexts • Researcher almost always identifies contextual and setting factors as they relate to the phenomenon of interest • Researcher can use the primarily qualitative method of grounded theory to inductively generate a tentative but explanatory theory about a phenomenon • Can determine how participants interpret constructs • Data are usually collected in naturalistic settings in qualitative research • Qualitative approaches are especially responsive to local situations, conditions, and stakeholders' needs • Qualitative researchers are especially responsive to changes that occur during the conduct of a study and may shift the focus of their studies as a result	• Testing and validating already constructed theories about how and why phenomena occur • Testing hypotheses that are constructed before the data are collected • Can generalise research findings when the data are based on random samples of sufficient size • Can generalise a research finding when it has been replicated on many different populations and subpopulations • Useful for obtaining data that allow quantitative predictions to be made • The researcher may construct a situation that eliminates the confounding influence of many variables, allowing one to more credibly establish cause-and-effect relationships • Data collection using certain quantitative methods is relatively quick (e.g. telephone interviews) • Provides precise, quantitative, numerical data • Data analysis is relatively less time consuming (using statistical software) • The research results are relatively independent of the researcher (e.g. statistical significance) • It is useful for studying large numbers of respondents.
Weaknesses	• Knowledge produced may not be generalised to other people or other settings (i.e., findings may be unique to the relatively few participants included in the research study) • It is difficult to make quantitative predictions. • It is more difficult to test hypotheses and theories with large participant pools • There may be perceived issues with the credibility of outcomes. • It generally takes more time to collect the data when compared to quantitative research. • Data analysis is often time consuming. • The results are more easily influenced by the researcher's personal biases and idiosyncrasies	• Researcher's categories that are used might not reflect local constituencies' understandings • Researcher's theories that are used might not reflect local constituencies' understandings • Researcher might miss out on phenomena occurring because of the focus on theory or hypothesis testing rather than on theory or hypothesis generation (called the confirmation bias) Knowledge produced might be too abstract and general for direct application to specific local situations, contexts, and individuals

Table 5. 4: *Pros* and *cons* of using mixed methods
(Sources: Creswell, 2008; Fellows and Liu, 2008; Tashakkori and Teddlie, 2010; Creswell and Piano Clark, 2013)

***Pros* of using mixed methods**	***Cons* of using mixed methods**
• Mixed method research provides strengths that offset the weakness of quantitative research e.g. quantitative research is arguably weak in understanding the context or setting in which people talk; the voices of participants are not directly heard; researchers are in the background and their own personal biases and interpretations are seldom discussed. Qualitative research therefore makes up for these weaknesses. • It also provides strengths that offset the weakness of qualitative research e.g. qualitative research is seen as deficient because of personal interpretations made by the researcher; the ensuing bias by this; and the difficulty in generalising findings to a large group because of the limited number of participants studied. Quantitative research therefore makes up for these weaknesses. • Mixed methods research provides more evidence for studying a research problem than either quantitative or qualitative research alone. • Researchers are enabled to use all of the tools of data collection available rather than being restricted to the types of data collection typically associated with quantitative research or qualitative research. • Mixed methods research helps answer questions that cannot be answered by quantitative or qualitative approaches alone. For example, ‘Do participant views from interviews and from standardised instruments converge or diverge?’ is a mixed methods question. • Mixed methods provides a bridge across the sometimes adversarial divide between quantitative and qualitative researchers as divisions between quantitative and qualitative research only serve to narrow the approaches and the opportunities for collaboration. • Mixed methods research encourages the use of multiple worldviews, or paradigms, rather than the typical association of certain paradigms with quantitative research and others for qualitative research. • Mixed methods research is ‘practical’ in the sense that the researcher is free to use all methods possible to address a research problem.	• Mixed method is a realistic approach only if the researcher has the requisite skills. The researcher need to gain in-depth experiences first with both quantitative research and qualitative research separately before undertaking a mixed methods study. Researchers undertaking this approach to research need to have a solid grounding in mixed methods research. • Even when researchers have basic quantitative and qualitative research skills, mixed methods approach may not always be feasible given time and resources. These are important issues to consider early in the planning stage. Mixed methods studies may require extensive time, resources, and effort on the part of the researchers. • Mixed methods research is relatively new in terms of methodologies available to researchers. As such, others may not be convinced of or understand the value of mixed methods. Some may see it as a ‘new’ approach. Others may feel that they do not have time to learn a new approach to research, and some may object to mixed methods on philosophical grounds regarding the mixing of different philosophical positions. • Mixed methods studies can be difficult to locate in the literature, because only recently have researchers begun to use the term mixed methods in their titles or in their methods’ discussions. Also, some disciplines may use different terms for naming this research approach.

The arguments for using mixed methods (*pros*) for this study are stronger than the arguments against (*cons*). The main arguments against mixed methods are that it is tedious, time consuming, and requires researcher skills. However, these have all been taken into consideration by the researcher and provisions made to mitigate such effects. The strong argument in support of mixed methods is that the qualitative method covers the aspects not covered by quantitative methods and vice versa in the same research. Since the research adopts exploratory sequential mixed methods, the details of the qualitative data collection and analysis, and quantitative data collection and analysis are will be discussed.

5.4 QUALITATIVE DATA COLLECTION AND ANALYSIS

Various options were considered for data collection for qualitative procedures out of which one was selected for this study. The options include (Creswell, 2008; Denzin and Lincoln, 2011):

- Observations; are those in which the researcher takes field notes on the behaviour and activities of individuals at the research site. In these field notes the researcher records in an unstructured or semi-structured way, activities at the research site. Observers may also engage in roles varying from a non-participant to a complete participant.
- Documents; qualitative data can be collected through public documents such as minutes of meetings and official reports, or private documents such as personal journals and diaries.
- Audio-visual materials; qualitative data can be collected from audio and visual materials which can take the form of photographs, art objects, videotapes or any forms of sound.
- Interviews; qualitative data can be collected through interviews where the researcher conducts face-to-face interviews with participants, interviews

participants by telephone or engages in focus group interviews with 6 to 8 interviewees in each group. Interview questions are usually few in number, typically open-ended intended to elicit views and opinions from the participants.

Interviews were selected as the preferred method for qualitative data collection for the study because it provides the best avenue for participants to share their experiences, expertise and inner perceptions with the interviewer. The nature of the research questions for the study do not require observations of participants or activities at the research site but are based on years of professional experiences and insights of individual participants. The qualitative data collection procedure for the study does not require direct abstractions from public or private documents neither does it require direct abstractions from audio-visual materials. Interviews were therefore selected as most appropriate for the study. Based on the degree of structuring, interviews can be divided into three categories: structured interviews, semi-structured interviews, and unstructured interviews (Fontana and Frey, 2005; Denzin and Lincoln, 2011).

A structured interview has a set of predefined questions and the questions would be asked in the same order for all respondents. This standardisation is intended to minimise the effects of the instrument and the interviewer on the research results. Structured interviews are similar to surveys except that they are administered orally rather than in writing. Semi-structured interviews are more flexible. An interview guide, usually including both closed-ended and open-ended questions, is prepared but in the course of the interview, the interviewer has a certain amount of room to adjust the sequence of the questions to be asked and to add questions based on the context of the participants' responses. Unstructured interviews can be defined as interviews in which neither the question nor the answer categories are predetermined. Instead, they rely on social interaction between the interviewer and the participant. Unstructured interviews have been described as a way to understand the complex behaviour of people without imposing any a priori categorisation which might limit the field of inquiry. In considering the most appropriate option for the study, the strengths and weaknesses of each type of interview were examined (See Table 5.5).

A useful concept in describing types of interview is the continuum; any particular interview can be placed somewhere between 'unstructured' and 'structured'. The 'unstructured' pole is closer to observation, while the 'structured' use of 'closed' questions is similar to types of questionnaire. The nature of the research problem and the research questions to be addressed situates somewhere in the middle of the continuum therefore requiring semi-structured interviews as a procedure of enquiry on the impact of knowledge management in reducing the cost of poor quality in construction. Also having considered the strengths and weaknesses of the three categories of interviews, semi-structured interviews were selected as the most appropriate for the study because they draw from the strengths of structured and unstructured interviews while offsetting their weaknesses; in which case the 'rigidity' of structured interviews and the 'laxity' of unstructured interviews are compensated for using semi-structured interviews. The practicality of using semi-structured interviews were duly considered, which include factors of time, cost, and the capabilities of the researcher in handling interviews and interviewees.

Table 5. 5: Strengths and weaknesses of structured, semi-structured and unstructured interviews
(Sources: Fontana and Frey, 2005; Denzin and Lincoln, 2011)

	Structured interviews	**Semi-structured interviews**	**Unstructured interviews**
Strengths	• Enables the researcher to examine the level of understanding a respondent has about a particular topic usually in slightly more depth than with a postal questionnaire. • Can be used as a form of formative assessment before using a second method e.g. observation or in-depth interviewing • All respondents are asked the same questions in the same way, making it easy to replicate the interview i.e. research method is easy to standardise • Provides a reliable source of quantitative data. • The researcher is able to contact large numbers of people quickly, easily and efficiently • It is relatively quick and easy to create, code and interpret. • There is a formal relationship between the researcher and the respondent with the latter knowing exactly what is required from them in the interview. • The researcher does not have to worry about response rates, biased samples and incomplete questionnaires	• Positive rapport between interviewer and interviewee. • Very simple, efficient and practical way of getting data about things that can't be easily observed • High validity: people are able to talk about something in detail and depth. The meanings behind an action may be revealed as the interviewee is able to speak for themselves with little direction from interviewer. • Complex questions and issues can be discussed or clarified • The interviewer can probe areas suggested by the respondent's answers, picking up information that had either not occurred to the interviewer or of which the interviewer had no prior knowledge. • Pre-judgement: problem of researcher pre-determining what will or will not be discussed in the interview is resolved. With few pre-set questions involved, the interviewer is not pre-judging what is and is not important information. • Easy to record interview e.g. video / audio tapes	• The interaction between the participant and the interviewer allows for richer, more valid data. This is because the interviewer can ask follow up questions • Also the interaction allow the interviewer to develop a relationship with the participant which could mean they are more open and honest with their answers • Ambiguities in an answer can be probed to further understand the meaning of that answer • The interviewer can change the questions if, over the course of the study they think the hypothesis should change or they want to take the study in a new direction • Provides highly detailed and valid data. • Extremely flexible. • Natural and unrestricted, it can reveal more about the participant.
Weaknesses	• Can be time consuming if sample group is very large because the researcher needs to be present during the interviews. • The quality and usefulness of the information is highly dependent upon the quality of the questions asked. • The interviewer cannot add or subtract questions. • Substantial amount of pre-planning is required. • The format of questionnaire design makes it difficult for the researcher to examine complex issues and opinions. • There is limited scope for the respondent to answer questions in any detail or depth • There is the possibility that the presence of the researcher may influence the way a respondent answers various questions, thereby biasing the responses. This is known as the interview effect.	• Depends on the skill of the interviewer and articulacy of respondent. • Interviewer may give out unconscious signals or cues that guide respondent to give answers expected by interviewer. • Time consuming and expensive • Not very reliable: difficult to exactly repeat interviews; respondents may be asked different questions (non-standardised); samples tend to be small. • Depth of qualitative information may be difficult to analyse e.g. deciding what is and is not relevant; personal nature of interview may make findings difficult to generalise; respondents may effectively be answering different questions. • Validity: the researcher has no real way of knowing if the respondent is lying; the respondent may not consciously lie but may have imperfect recall.	• With unstructured interviews a trained interviewer is required who can only interview one participant at a time, this means this method is time-consuming and costly • The interviewer does not ask exactly the same question every time, it can therefore be said that this method is less reliable • The changing questions also mean it is difficult to replicate the study. • The data is qualitative which means it is hard to analyse and compare with other pieces of data • Unstructured interviews can take up a great amount of time and cost for the interviews to take place. • Problem with reliability and generalising.

Finally the use of semi-structured interviews meets the overall research objectives, the details of which are discussed in the next sub-section.

5.4.1 Design of the semi-structured interviews

The interviews were carefully designed to elicit the interviewees' in-depth ideas, opinions and responses to each research question together with the follow on questions. A researcher-completed semi-structured interview template was developed to ensure consistency in the approach to which the interviews were conducted. The interview questions stems from extensive literature review and the development of a conceptual framework on the impact of knowledge management in reducing the cost of poor quality in construction. Four levels of knowledge management relating to the construction industry were identified from literature review namely; personal, organisational, project and industry. Three main contributory factors to the cost of poor quality were also identified from literature namely; design changes, errors and omissions, and poor skills.

The main research questions to be addressed are linked to knowledge management levels and the contributory factors of the cost of poor quality. These are therefore incorporated into the semi-structure interview template thus: (1) What are the contributory factors to the cost of poor quality in practice? (2) What is the impact of knowledge management in reducing the cost of poor quality based on the contributory factors? (3) What are the barriers to the optimisation of knowledge management to reduce the cost of poor quality? An interview template was developed as a guide for the interviewer (researcher) in order to ensure consistency in the way in which the questions are put forward to the interviewees (See Appendix 4). The template consists of three sections. Section A contains general information about the interviewee such as; how many years of construction industry experience do you have? Which types of construction projects have you worked on? What types of organisations have you previously worked for?

Section B investigated the contributory factors to the cost of poor quality on projects. The questions to be addressed under this section are related to the contributory factors to the cost of errors and omissions, design changes and poor skills in construction projects. Section C investigates the impact of knowledge management in reducing the cost of poor quality based on the identified contributory factors. Section D investigates the barriers to the optimisation of knowledge management to reduce the cost of poor quality.

Apart from the main questions, follow-on questions were posed to the interviewee to further probe into the original questions asked e.g. 'can you please elaborate on….' Other follow-on questions include the use of 'why…', 'how…', 'which…', and 'when…' The objective is to explore the research questions in details, particularly to identify what types of knowledge management initiatives were set in place by construction organisations at personal, organisational, project and industry levels to reduce the costs associated with design changes, errors and omissions, and poor skills. The researcher-completed template served as a guide for the interviews however the details of the interview were recorded through the use of digital audio equipment.

5.4.2 Pilot study debate for semi-structured interviews

A pilot study refers to a small scale preliminary study conducted in order to evaluate feasibility, time, cost, adverse events as well as the specific pre-testing of a particular research instrument such as a questionnaire or interview schedule (Teijlingen and Hundley, 2001). This can also be referred to as a mini version of a full scale study. While a pilot study may be extremely useful for a questionnaire survey, it may be argued otherwise in the case of semi-structured interviews. According to Baker (1994) supported by Polit et al., (2001), a pilot study can be the pre-testing or trying-out of a particular research instrument in preparation for the major study, however most semi-structured interviews utilise very basic instruments if any is used at all, therefore may not require prior testing. Although pilot studies can be useful for semi-structured interviews for certain studies but in the context of this research, the need for a pilot study cannot be truly justified.

It is acknowledged that pilot studies can be used to acquire early contextual sensitivity through the collection of essential information for effective research design and development of greater awareness of dynamic events, agents and circumstances that can positively modify the research process flow and affect decision-making. Moreover, pilot studies hold the potential of minimising problems associated with cold, unreflecting immersion in the field. De Vaus (1993) therefore warned that to avoid unpleasant surprises, “do not take the risk, pilot test first” This position suggests that a considerable advantage of conducting a pilot study is anticipating the debilities of the research project, namely by controlling the adequacy of protocols, methods and instruments.

Sampson (2004) also suggested that it is often only when data is evaluated that any gaps in a research design begin to show up, hence running a pilot can save time invested in unfeasible projects.

Contrary to the supporting arguments, pilot studies are not without drawbacks especially where data from the pilot study are included in the main results. This is more so where pilot participants are included in the main study, but new data are collected from these people. However, Teijlingen and Hundley (2001) argue that contamination is less of a concern in qualitative research, where researcher so often use some or all of their pilot data as part of the main study. Some researchers have therefore argued that in qualitative approaches separate pilot studies are not necessary (e.g. Holloway 1997). Having considered the merits and demerits of using a pilot study, it was concluded that it was not entirely necessary for the semi-structured interviews due to the following explanations:

- The semi-structured interviews for this study are exploratory in nature therefore any data collected during the ‘pilot study’ would have also been used in the ‘main study’ data analysis. Utilising a pilot study would therefore be superfluous. Moreover the exploratory nature of the interviews does not require an additional feasibility.
- A pilot study has been defined as a small scale preliminary study pre-testing a particular research instrument such as a questionnaire or interview schedule for a bigger study. In the case of the semi-structured interviews for this research, the instrument involved is the interview template containing three main research questions relating to the impact of knowledge management in reducing the cost of poor quality in construction.

- Pilot studies hold the potential of minimising problems associated with cold, unreflecting immersion in the field. In the case of the semi-structured interviews for the study, the researcher is conversant in conducting interviews and is familiar with construction organisational territory therefore does not envisage issues in dealing with participants.
- Undertaking a pilot study for the semi-structure interviews is time consuming and not cost effective.

Since pilot studies are deemed fit for large scale surveys rather than small scale in-depth or exploratory interviews, the research utilises pilot study for the quantitative element (questionnaire survey) rather than the qualitative element (semi-structured interviews)

5.4.3 Sampling strategy

There are several sampling techniques available in research, all of which can be classified under two sampling strategies namely probability sampling (e.g. simple random sampling, stratified random sampling, cluster sampling) and non-probability sampling (e.g. purposive sampling, homogeneous sampling, snowball sampling). The details of sampling strategies and techniques have been elaborated by Patton (1990), Mutes and Huberman (1994), Omwuegbuzie and Leech, (2007). In probability sampling, every subject in the population has a known, non-zero probability of being included in the sample. In non-probability sampling, the probability of inclusion of each subject is not known and many of the elements may have zero probability (Gillham, 2000; Churchill and Lacobucci, 2002; Creswell, 2008). Non-probability sampling strategy was adopted in the selection of interviewees due to its suitability for in-depth qualitative research in which the focus is to understand complex social phenomena (Marshall 1996; Creswell 2009). Purposive sampling was applied as a technique and a crucial element to the strategy which enabled a deliberate selection of the most appropriate interviewees for the study. Expert sampling was utilised as a sub-technique to identify and select interviewees with the required expertise who could provide credible insight into the study. The interviewees were selected from industry communities of practice and expert forums across UK based on eligibility criteria which included project experience, organisational experience and job designation (see Table 5.6).

Table 5. 6: Profile of interviewees

Interviewee ID	Years of experience	Project experience*	Organisation experience*	Current designation
A	40	1, 2, 3, 4, 5, 6	1, 2, 3, 5, 8	Director/continuous improvement
B	35	1, 6	1, 2, 3, 4, 8	Director/architecture
C	33	1, 2, 4, 6	1, 2, 3, 4, 7	Supply chain manager
D	32	1, 6	1, 2, 3, 7	Senior consultant/strategy innovation
E	30	1	1, 2, 3, 5	Director/supply chain knowledge management
F	30	1	1, 2, 3	Director/technology
G	30	1, 2	1, 2, 3	Director/performance improvement
H	29	4	3, 4	Project design engineer
I	25	1	1, 2, 3	Cost consultant
J	23	1, 2, 3	1, 2, 3	Director/knowledge management
K	23	1, 2, 4	2, 3, 6	Director/operations
L	15	2	2, 3	Site engineer
M	14	4	2, 3, 4, 5	Project engineer
N	14	1, 2, 3, 4, 5	2, 3, 5	Projects control manager
O	14	4	2, 3, 5	Project risk engineer
P	12	1	3, 5	Project manager
Q	12	4	3, 4	Senior design engineer
R	10	1, 2	2, 3	Change manager/ knowledge management
S	10	4	3, 4	Project design engineer
T	8	5	1, 3	Project engineer
U	8	2	3	Site surveyor
V	8	5	1, 3	Engineer/water
W	7	1	3	Senior quantity surveyor
X	6	4	3	Design engineer
Y	5	4	3	Design engineer

*Key

Project experience	Organisation experience
1 – Building construction	1 – Client organisation
2 – Highways	2 – Consultancy
3 – Rail	3 – Main contractor
4 – Utility (power)	4 – Design organisation
5 – Utility (water)	5 – Project management
6 – Other	6 – Sub-contractor
	7 – Supplier
	8 – Other

The interviewees have acquired years of experience in large construction organisations (over 250 employees) particularly with main contractors, and have been involved in a diverse range of projects. Although the UK construction industry is made up mostly of small and medium sized organisations (up to 250 employees), large organisations particularly the main contractors undertaking large projects tend to engage several of these smaller organisations in their supply chain (BIS 2013). The study therefore adopted a top-down approach by selecting interviewees from the main contractor organisations.

The sample size grew up to 25 interviewees at which point saturation was reached whereby data collection neither led to more information nor gave further insight into the study (Crouch and McKenzie, 2006). The sample size nevertheless falls within what is acceptable for qualitative research of this nature (Morse, 2003). Depending on interviewee's proximity and convenience, 60% of the interviews were conducted face-to-face, 28% by video call and 12% by telephone. The interviews lasted for 2 hours averagely.

5.4.4 Analysis of the semi-structured interview data

As discussed in the earlier sections, qualitative data analysis seek to describe textual data in ways that capture the setting or participants who produced the text on their own terms rather than in terms of predefined measures and hypotheses. What this means is that qualitative data analysis tends to be inductive. The researcher therefore identifies important categories in the data, as well as patterns and relationships, through a process of discovery. Good qualitative data analyses also are distinguished by their focus on the interrelated aspects of the setting, group, or person under investigation. For this research the semi-structured interview data was analysed utilising the steps highlighted by Creswell (2008). They are presented as follows:

1. Organise and prepare the data for analysis
2. Read through all the data. Gain a general sense of the information and reflect on the overall meaning.
3. Conduct analysis based on the specific theoretical approach and method. This involves coding or organising related segments of data into categories.
4. Generate a description of the setting or participants and identify themes from the coding. Search for theme connections.
5. Represent the data within a research report.
6. Interpret the larger meaning of the data

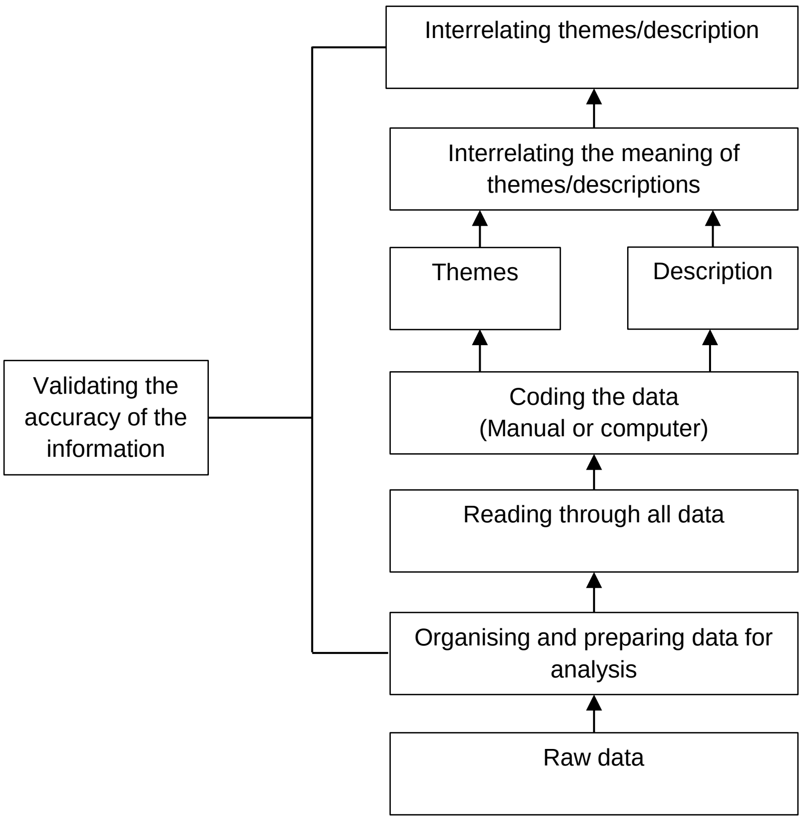


Figure 5. 2: Data analysis for qualitative research
(Source: Creswell 2008)

These steps are elaborated in a diagram format (see Figure 5.2), which shows the process of analysis from the collection of raw data to the validation of the accuracy of the information obtained. These are further discussed in sub-sections 5.4.4.1 to 5.4.4.6.

5.4.4.1 Organising and preparing the data for analysis

All the interview sessions were audio-recorded on a digital audio recorder. According to Patton (2002), no matter what style of interviewing is used and no matter how carefully the questions are worded, it all becomes naught if the interviewer fails to capture the actual words of the person being interviewed. However the recordings did not eliminate the need for taking field notes, but did allow the interviewer to concentrate on taking strategic and focused notes, rather than attempting verbatim notes. The manual taking of notes were also useful to help formulate new questions as the interview progressed. The recordings were listened to by the researcher several times to gain more insight, and better understanding of what the interviewees were trying to convey in broader terms and within the context of the study.

5.4.4.2 Reading through all the data

The next step was to convert the interview data into written form. The interview recordings were transcribed verbatim into Microsoft Word document. The transcriptions were read and re-read to gain a general sense of the information and again reflect on the overall meaning. Further impressions about the interview data was written down and noted for use in the subsequent analysis.

5.4.4.3 Conducting analysis based on the specific theoretical approach and method

The interview data was analysed using content analysis, which is a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding (Weber, 1990; Krippendorff, 2004; Creswell, 2014). Nachmias and Nachmias (1996) suggested applications of content analysis which are: to describe the attributes of the message; and to make inferences about the effect of the message on the interviewer. The content that is analysed can be in any form to begin with, but is often converted into written words before it is analysed. The advantages of content analysis are that it is unobtrusive, accepts unstructured material, is context sensitive, can process symbolic forms, and can cope with large volumes of data (Krippendorff, 2004).

Perhaps the most common notion in qualitative research is that a content analysis simply means doing a word-frequency count. The assumption made is that the words that are mentioned most often are the words that reflect the greatest concerns. While this may be true in some cases, there are several counterpoints to consider when using simple word frequency counts to make inferences about matters of importance. One thing to consider is that synonyms may be used by interviewees or even regional dialects (e.g. the interviewees for this study originate from different parts of the United Kingdom) and thus may lead the researcher to underestimate the importance of a concept (Weber, 1990; Babbie, 2004). Also important to note is that each word may not represent a category equally well. In performing word frequency counts therefore, it is worthy to note that some words may have multiple meanings. For instance the word 'state' could mean a political body, a situation, or a verb meaning 'to speak'. As a result, this study adopted a thematic approach to content analysis which focused on identifying and describing both implicit and explicit ideas within the data i.e. themes. Consideration for this approach was based on its appropriateness in advancing beyond counting words or phrases and focusing on drawing interpretation and meaning consistent with the data collected (Hatch, 2002).

Nachmias and Nachmias (1996) noted that in content analysis, the researcher can guarantee objectivity by carrying out analyses according to explicit rules that enable different investigators to obtain the same results from the same messages or documents. The researcher therefore maintained this objectivity in analysing the data. Content analysis can be done manually or through the use of computer programs such as NVivo. Although computers can assist in organising and indexing qualitative data, they do little with the analysis of the data particularly relating to themes and meanings being conveyed by interviewees. The qualitative aspect of this study involved twenty five (25) interviewees and it was decided to conduct the analysis manually since this number was manageable enough for a rigorous thematic analysis.

5.4.4.4 Generating a description of the setting or participants and identifying themes from the coding

The interview data analysis involves coding and organising related segments of the data into categories. Codes are tags, names or labels, and coding is therefore the process of putting tags, names or labels against pieces of data (Miles and Huberman, 1994; Huberman and Miles, 2002). The pieces may be individual words, small or large chunks of the data. The point of assigning labels is to attach meaning to the pieces of data and these labels serve a number of functions. They index data, providing a basis for storage and retrieval. The first labels permit more advanced coding which enables the summarising of data by pulling together themes and by identifying patterns. In view of the volume and complexity of much qualitative data, these early labels become an essential part of subsequent analysis. In the Miles and Huberman’s (1994) approach, there are two main types of codes: (1) descriptive codes and (2) inferential (or pattern, or thematic) codes. Early labels may be descriptive codes requiring little or no inference beyond the piece of data itself.

There are especially valuable in getting the analysis started and in enabling the researcher to get a ‘feel’ for the data. Glaser and Straus (1967) use the term ‘in vivo’ codes in the same way in grounded theory coding. Richards (2005) uses the term ‘topic’ coding in much the same way. First level coding mainly uses descriptive, low inference codes which are very useful in summarising segments of data and which provide basis for later higher order coding (Miles and Huberman, 1994; Huberman and Miles, 2002). In this research, the descriptive coding covers the first section of the interview template in which interviewees are asked questions such as: How many years of construction industry experience do you have? Which types of construction projects have you worked on? Table 5.6.1 shows the excerpts from the coding of the transcript of Interviewee A. Later codes are more interpretive, requiring some degree of inference beyond the data. Thus second level coding tends to focus on pattern code. A pattern code is more inferential and a sort of ‘meta-code’ (Miles and Huberman, 1994; Huberman and Miles, 2002). Pattern codes pull together material into smaller more meaningful units. There is usually the range of possibilities when it comes to bringing codes to the data or finding them in the data. At one end of the continuum there are pre-specified codes or more general coding frameworks. At the other end there are no pre-specified codes but the data suggests the initial codes. An example is shown in Table 5.6.2 which is an excerpt from coding of Section A of the interview transcript of Interviewee H. The pattern ‘rule-based mistakes’ and ‘slips/lapses of attention were drawn from the response data. Table 5.6.3 and Table 5.6.4 show the excerpts from how different interviewees respond to the same question. This allows for deduction of common themes and patterns from the data.

Table 5.6.1: Excerpts from the coding of Section A of the interview transcript

Interview questions (Researcher)	**Excerpts from interviewee response (Interviewee A)**	**Descriptive codes (Researcher)**
Q1. How many years of construction industry experience do you have?	*“I’ve been in this industry 40 odd years…”*	40 years
Q2. Which types of construction projects have you worked on?	*“All sorts, I’ve worked on a wide range of projects including building projects both private and commercial. I was involved in Network Rail projects, highway projects, National Grid project construction, Water projects, infrastructure to name a few”*	Building construction Highways Rail Utility (power) Utility (water) Other

Table 5.6.2: Excerpts from the coding of Section B of the interview transcript

Interview questions (Researcher)	Excerpts from interviewee response (Interviewee H)	Inferential/pattern codes (Researcher)
Q1. From your experience of construction projects, what are the contributory factors to the cost of errors and omissions on projects?	*"There are several causes…I can recall this example where during a power line project, the drawing office was basically said to do the setting out foundation drawing for a particular tower (pylon). These towers are square at the bottom and the taller the tower gets the bigger the square at the bottom. He (the design engineer) just went and he basically designed for what he thought was the right size tower*[RB]. The drawing went out to site. They dug the holes and put the steelwork into it. They poured the concrete. Then came along to build the tower, unfortunately the tower was bigger so the tower was never going to fit on the foundation nobody picked it up checking what the height of the tower should have been against the width of the foundation*[SLA] so they basically had to then dig those foundations out and then go and put them back in. And the boss said to the design engineer that didn't do the checks, he said you are just going to cost us fifty thousand quid on that job, and the delay and all because somebody hasn't done the check*[SLA]".*	*[RB] Rule-based mistakes *[SLA] Slips/lapses of attention
Q2. What are the causes of design changes during projects?	*"Design change can happen due to ground conditions on site*[USC]. If you are unable to actually get into the site to carry out ground investigation early in the project due to lack of time*[TC] and the only thing you can do is basically do your desktop exercise by going through your geological maps et cetera and the records of any existing borehole taken around that area and assume the price of different types of say foundations you will possibly be putting in. Hopefully you get the job and you finally get on the site and start drilling holes. Where you end up with a problem is if you suddenly find you've got different ground conditions from the ones planned for*[USC]. Sometimes you have to change the design basically get the design out to your piling contractor or your foundation contractor especially if you have to put your design through some third party designer, they've got a lead time and that does cause a problem then*[PS]. So the thing you should have been doing has suddenly got delayed and that does hit your programme.*	*[USC] Unforeseen site conditions *[PS] Procurement strategy *[TC] Time constraints

Table 5.6.3:
Excerpts from the coding of Section B of the interview transcript showing theme connections

Interviewee ID	**Q2. From your experience of construction projects, what are the contributory factors to the cost of design changes? Excerpts from Interviewee responses:**	**Inferential/pattern codes (Researcher)**
Interviewee A	*"I was part of the team that built the shopping centre, most of the design changes was due to the client changing their minds…"*	Client change
Interviewee B	*"…design change can be due to client change because they are not very good at communicating with the professional team to identify what they want at the inception…"*	
Interviewee C	*"…the quality of information on the drawings is not good enough to allow people to work from those drawings. Clients also tend to change design specifications frequently…"*	
Interviewee D	*"…sometimes changes are needed really because of the evolution of the design in generalities obviously some changes are because the client physically changes his mind and the key thing to me with regard to changes is that they are inevitable".*	
Interviewee E	*"…during the construction of a multi-story building, the client suddenly wants a swimming pool on the 40th floor. This cost a lot of money and time. There will always be design changes during the life of a project. It keeps changing and nothing can be done about it".*	
Interviewee F	*"…so where you might take a contract for thirty eight million pounds you know it's going to end forty four how many design changes usually by the client you have to go through. Expect more time in the design and planning, quantifying cost before you went to submit, that's the trick".*	
Interviewee G	*"…that's where designers should be made to design to cost from the onset so they build-in products and materials that are appropriate to cost that the client can afford so you build it up using the correct components and avoid future design changes by the client".*	
Interviewee H	*"Client change is common in projects. People go ahead to design without adequate information or knowledge about what the project entails".*	
Interviewee I	*"…that's generally where the client isn't given approval brief or the client then starts saying this was all going to be agreed at a later stage now we want to agree a fit out sale not before you got the shell built…some clients just think oh well I'm paying the bills I can change my mind whenever I want, still get it done on time and on price and everything that's when you run into trouble on these big and complex projects"*	
Interviewee J	*"Clients change the design because they change their minds, they make irrational decisions to change it for a reason based on the information that they have…"*	

Table 5.6.4:
Excerpts from the coding of Section C of the interview transcript showing theme connections

Interviewee ID	**Q1: Which knowledge management initiatives were in place on the projects you worked on? Excerpts from Interviewee responses:**	**Inferential/pattern codes (Researcher)**
Interviewee A	" …we keep working on apprenticeships*[TQ/*Pn/*Or]. I don't think there's enough emphasis put on upskilling because there is limited budget…"	
Interviewee B	"We went through this process which proved to be completely abortive in actually trying to formalise all the systems in place put them on a computer basically so people press a button and see how things work*[TG/*Or] which was essentially a way of reducing the number of staff. We were just toying with a dedicated webpage where you feed everything in through, what source of information we get exchanged through the internet in a formal way*[TG/*Or]. Everybody was up to date with latest information"	
Interviewee C	"We are developing a lessons-learnt management system*[TG/*Or/*Pr]. When you go from one project to the next project you start with a set of processes which are usually just templates which do not necessarily have the lessons learnt from the last project, so your starting point is always going to be the base stand and then you are in the project delivery mode so everything you've learnt on your other projects goes out of the window. The system takes care of this".	*[TQ] KM technique *[TG] KM technology
Interviewee D	"We have a local intranet and knowledge based where project knowledge is stored and easily assessable*[TG*/Or/*Pr]. There would be a little piece saying when you are welding one bit of steel to another and its minus degrees in Russia and this steel comes from Romania you may well get a crack whereas you do exactly the same steel comes from the UK and you are welding it together you won't have the same problem".	*[Pn] Personal-level KM *[Or] Organisational-level KM
Interviewee E	"We retain most of our supply chain of about 60 companies and use them from project to project*[TQ/*Or]/*[Pr]. The benefit of this is that significant project knowledge is retained within the chain. There is a level of trust within the chain since they are rest assured that they will be working together for a long time The environment of trust therefore encourages knowledge sharing among parties*[TQ/*Or]/*[Pr]".	*[Pr] Project-level KM *[In] Industry-level KM
Interviewee F	"…it's capturing in some way that knowledge I mean look at the BIM projects the theory is there isn't it but whether you end up doing everything and then its stored away you never go back to use it. We don't seem to capture knowledge of individuals rather than the organisation. We focus more on the knowledge capture of individuals*[TQ/*Pn]"	
Interviewee G	"We have the knowledge bank*[TG*Or], we have technical excellence groups*[TQ*Or]. The technical excellence groups review the knowledge and the problems and everything that come up and decide what in our process is on our system our core processes and systems we have to change to make sure that wouldn't happen again. And then we have a number of publications which we produce that goes through the main functions and operations*[TG*Or]…"	

5.4.4.5 Representing the data within a research report

The identified patterns or themes within the data were organised into coherent categories that summarised and brought meaning to the text. This involved reading and re-reading the text and identifying coherent categories. The themes and connections were used to explain the findings which are presented and discussed in details in Chapter 6.

5.4.4.6 Interpreting the larger meaning of the data

This aspect presents the findings from the data analysis and synthesises the findings with the interview questions and with the overall research questions. This interpretation of the larger meaning of the data is presented in Chapter 6.

5.5 QUANTITATIVE DATA COLLECTION AND ANALYSIS

The need for a quantitative procedure was based on the sequential exploratory research strategy which involves a first phase of qualitative data collection and analysis, followed by a second phase of quantitative data collection and analysis that builds on the results of the first qualitative phase. It was discussed in the previous sections that a quantitative method can be executed either by experiments or by surveys. Experiments however were not considered for this research as they do not fit into the overall research aims and objectives. Rather than perform experiments to test theory, the research adopts the use of survey for the purpose of generalising the findings from the qualitative study i.e. semi-structured interviews. Surveys can take several forms which include; respondent-completed documents (e.g. postal or electronic questionnaires), face-to-face (personal) interviews, and telephone interviews. Surveys are, however prone to three main flaws (Mitchell and Jolley, 2001); researcher not knowing what he or she wants, poor construct validity of measures, and poor external validity when biased samples are used. These flaws however can be mitigated thoughtful planning and design of surveys. In this regard several authors (e.g. Fowler, 2002; Scheuren, 2004; Czaja and Blair, 2005; Dillman, 2007) provide useful guidance in this area. The choice of survey method for this study was based on the *pros* and *cons* of each, which includes the considerations for the sample population, characteristics of the sample, types of questions, question topic, response rate, costs and time (Table 5.7). Having considered the methods, postal survey was chosen for the following reasons:

- Adopting face-to-face or telephone surveys for this study would be impracticable and costly due to the sample size and the nature of the questionnaire.
- The length and format of the questionnaire is not entirely suitable for internet survey. Respondents may find the internet version tedious and may be discouraged to continue after clicking on a few pages. This may lead to low response rate.
- The relatively lower cost of administering postal questionnaire survey to the sample size was a key determinant in using postal survey.

Table 5. 7: *Pros*, *cons* and comparison of data collection methods for surveys

(Sources: Mitchell and Jolley, 2001; Fowler, 2002; Scheuren, 2004; Czaja and Blair, 2005; Dillman, 2007)

	Face-to-face interview survey	Telephone survey	Postal survey	Internet survey
Pros	• Generally yields highest cooperation and lowest refused rates • Allows for longer more complex interviews • High response quality • Takes advantage of interviewer presence • Multi-method data collection	• Less expensive than face-to-face interviews • Random digit dialling samples of general population • Shorter data collection period than face-to-face interviews • Interviewer-completed questionnaire • Better response rate than postal survey	• Less expensive than face-to-face, more expensive than internet • Can be administered by a smaller team of people (no filed staff) • Access to otherwise difficult to locate, busy populations • Respondents can look up information or consult with others	• Lower cost (no paper, postage, mailing, data entry costs) • Can reach international populations • Time required for implementation is reduced • Complex skip patterns can be programmed • Sample size can be greater
Cons	• Most costly procedure for survey data collection • Longer data collection period • Interviewer concerns e.g. Interviewing skills	• Biased against households without telephones, unlisted numbers • Non-response • Questionnaire constraints • Difficult to administer questionnaires on sensitive or complex topics	• Most difficult to obtain cooperation • No interviewer involved in collection of data • Need good sample • More likely to need incentives for respondents • Slower data collection period than telephone	• Not everyone can be reached via email • Differences in capabilities of respondents' computers and software for accessing internet surveys • Email surveys are easily overlooked by potential respondents as being of less priority
Comparison of methods				
Cost	Costly	Moderate	Moderate	Low
Speed	Slow	Fast	Moderate	Fast
Response rate	High	Moderate	Low to moderate	Low to moderate
Sampling need	Address	Telephone number	Address	Email
Burden on the respondent	Low	Moderate	High	High
Length of questionnaire	Long	Moderate	Moderate	Short
Sensitive questions	Poor	Moderate	Best	Moderate
Lengthy answer choices	Best	Moderate	Poor	Poor
Open-ended responses	Best	Moderate	Poor	Poor
Complexity of questionnaire	Best	Moderate	Poor	Moderate
Possibility of interview bias	High	Moderate	None	None

5.5.1 Questionnaire design

The purpose of the questionnaire in this study is to utilise quantitative data and results to assist in the interpretation of qualitative findings and to ascertain if the findings can be generalised in the wider construction industry context. The design of the questionnaire affects the richness' of the data collected, the number and quality of the responses, and the range of methods suitable for analysing the data gathered. The external and construct validity of surveys can generally be improved by the following actions (Mitchell and Jolley, 2001; Fowler, 2002): ensuring that the survey instrument promotes cooperation, is sufficient in detail and scope, and focuses on the objectives of study; ensuring that questions are clear, intelligible, logically sequenced, and match the knowledge-base of target respondents; and paying greater attention to the potential for sampling bias (especially non-response bias), interviewer bias and subject biases. Pilot testing the survey instrument before using it on a larger study can reasonably ensure these features are achieved. The questionnaire took a six-page Likert scale format excluding two introductory pages. This can be considered to be of a moderate length. Evidence from the literature suggested that the effect of questionnaire length on response rates have been mixed.

Denscombe (2003) showed that there is no correlation between questionnaire length and lack of response. According to Jankowicz (2005), the most important factor in assuring high response rate is whether the respondents are interested in the subject matter of the survey. Yates (2004) noted that a high response rate could be attained if the respondents are knowledgeable about the issues covered by the survey. The questionnaire design for the study commences with an introductory letter to the respondent introducing the researcher, the research institution and the research team. The letter briefly discusses the rationale for the research, overview of the research, benefits of the research especially to the respondent, aim of the questionnaire, key definitions and guidelines to completing the questionnaire, contact details of the researcher and the return address for the completed questionnaire. A consent form was attached to the letter which the respondents are required to sign and return to the researcher (See Appendix 3). The questionnaire consists of seven sections labelled from A to G (See Appendix 5).

- Section A contains general information about the respondents and their organisations. The information required include: years of experience in the construction industry; current job role; job level; number of employees in the organisation; organisations' area of operation; respondents' familiarity with knowledge management and quality management.
- Section B measures the impact of knowledge management in reducing the cost of poor quality on construction projects by presenting a list of knowledge management processes normally utilised in practice. The processes include knowledge identification, knowledge capture, knowledge codification, knowledge storage, knowledge sharing and dissemination. Respondents are required to rate from 1 to 4, the impact of these processes on the cost of design changes, cost of errors and omissions, and cost of poor skills. The rating scale represents; 1=strong negative impact, 2=negative impact, 3=positive impact, 4=strong positive impact.

- Section C measures the effectiveness of knowledge management techniques and technologies in reducing the cost of poor quality on construction projects. The techniques and technologies include brainstorming, collaborative workspaces, intranets, knowledge base, learning reviews etc. Respondents are required to rate from 1 to 4 the effectiveness of the techniques and technologies in reducing the cost of design changes, cost of errors and omissions, and cost of poor skills. The rating scale represents; 1=not at all effective, 2=fairly effective, 3=effective, 4=very effective.
- Section D measures the barriers to knowledge management in reducing the cost of poor quality. The barriers were identified from the qualitative data collection aspect of the research and they include; lack of senior management support, adversarial organisational culture, complacency of project staff, knowledge hoarding, high staff turnover, high perceived costs of investing in knowledge management initiatives etc. Respondents are required to rate these barriers on a scale of 1 to 4. The rating scale represents; 1=very weak barrier, 2=weak barrier, 3=strong barrier, 4=very strong barrier.
- Section E measures the benefits of reducing the cost of poor quality through the optimisation of knowledge management. The benefits include; improved cost efficiency, increased customer satisfaction, improved project performance, increased revenue for growth, increased competitive advantage etc. Respondents are expected to rate their level of agreement to each of the benefits on a scale of 1 to 4. The rating scale represents; 1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree.

- Section F investigates whether organisations measure the impact of knowledge management on the cost of poor quality on projects. It also investigates whether organisations currently have knowledge management tools for reducing the cost of poor quality in construction. This section contains a series of questions in which respondents are to answer either ‘yes’ or ‘no’.
- Section G gives the respondents opportunity to express their thoughts or add any comments relating to the content of the questionnaire. The section also contains a ‘thank you’ note, a question whether the respondent would like to have a copy of key findings. The survey design is cross-sectional rather than longitudinal, in other words the survey data is collected at one point in time rather than repeated observations of the same variables over long periods of time.

5.5.2 Piloting the survey

It was necessary to conduct a pilot survey for the questionnaire by administering the questionnaire to pilot subjects in exactly the same way as it will be administered in the main study. This enables feedback to be obtained from participants to: identify ambiguities and difficult questions; record the time taken to complete the questionnaire and decide whether it is reasonable; discard all unnecessary, difficult or ambiguous questions; assess whether each question gives an adequate range of responses; establish that replies can be interpreted in terms of the information that is required; check that all questions are answered ; re-word or re-scale any questions that are not answered as expected; shorten, revise and, if possible, pilot again.

5.5.3 Sampling strategy for the pilot survey

According to Jankowicz, (2005), pre-testing of the questionnaire should be carried out and that it should include different groups, such as colleagues and potential users of the data. In the case of the pilot survey, non-probability sampling strategy was adopted in the selection of respondents since the aim was to pre-test the questionnaire for the main study. Convenience sampling technique was used in identifying and selecting respondents from within the construction industry and academia based on their expertise and relative ease of access. An initial draft of the questionnaire was posted to ten (10) construction industry practitioners from large construction companies, six (6) of which were in management, and four (4) in operations. The questionnaire was also presented to four (4) academics, two of which were in senior positions. All of the selected respondents completed the questionnaire and returned their critiques and comments.

5.5.4 Contributions of the pilot survey to the main questionnaire design

The critiques and comments from the respondents were incorporated into the final version of the questionnaire such as; shortening the length of the questionnaire from eight pages to six pages, re-wording the instruction to respondents for more clarity, making the layout more attractive, re-calibrating the rating scales, re-ordering the sequence of questions and defining key terms. In doing this, the researcher ensured that the final questions were direct, specific, clear while avoiding double-barrelled questions, leading or emotive questions, and questions which are too complex or ambiguous. The finalised main questionnaire was subsequently signed off by the supervisory team to be administered to the selected industry practitioners.

5.6 ETHICAL CONSIDERATIONS FOR THE RESEARCH

Research involves collecting data from people (Punch, 2005), it is therefore important to anticipate ethical issues that may arise during research (Hesse-Bieber and Leavey, 2006). Researchers need to protect their research participants; develop a trust with them; promote the integrity of research; guard against misconduct and impropriety that might reflect on their organisations or institutions; and cope with new challenging problems (Israel and Hay, 2006). Interviewing in qualitative research is increasingly being seen as a moral inquiry. According to Kvale (2007), interviewers need to consider how the interview will improve the human situation as well as enhance scientific knowledge; how a sensitive interview interaction may be stressful for the participants, whether the participants have a say in how their statements are interpreted, how critically the interviewees might be questioned and what the consequences of the interview for the interviewees and the groups to which they belong might be.

Ethics approval was for this research was sought through the School of Architecture and the Built Environment, Faculty of Science and Engineering of the University of Wolverhampton. This was approved by the university’s ethics committee which also stipulated the following ethics approval guidelines that were adhered to by the researcher:

- Telephone contact with other individuals or organisations; Participants were fully informed of the risks and benefits of the procedures and of their right to refuse participation or withdraw from the research at any time
- Interviews; Final versions of the interview questions were submitted to the research supervisory team for confirmation of 'fitness for purpose' before any data is collected.
- Confidential information: Measures were put in place to ensure continued confidentiality. The confidentiality and anonymity of all participants were maintained during data collection, analysis, dissemination and subsequent storage in line with the Data Protection Act (1998).
- Research integrity: Under no circumstances were data fabricated to support any conclusion, regardless of how seemingly noble or interesting that conclusion might be. All findings were reported with the utmost professional honesty. In addition, full credit was given appropriately where deserved in the acknowledgment of this thesis.

In the case of the semi-structured interview aspect of the research, all the interview sessions were audio-recorded and the participants were made aware of this. Patton (2002) suggested that no matter what style of interviewing is used and no matter how carefully the questions are worded, it all becomes naught if the interviewer fails to capture the actual words of the person being interviewed. For this research, a digital voice recorder was used to capture the audio of the interviews. The recording of the interviews did not eliminate the need for taking field notes, but did allow the interviewer to concentrate on taking strategic and focused notes, rather than attempting verbatim notes. The manual taking of notes were also useful to help formulate new questions as the interview progressed. All audio recordings from the interviews were transcribed in preparation for data analysis.

Unlike semi-structured interviews which require direct contact with the participants, the quantitative procedure in this research involves the postage of questionnaires to respondents which they are required to self-complete. In this case the researcher clearly has the responsibility to fully inform participants about the nature of the activities in the process of obtaining consent, and make it clear to participants that their consent may be withdrawn and they may elect to discontinue the activities at any time. Ethical issues exist in conducting surveys where the researcher does not impose or manipulate conditions.

Although ethics in surveys are often less complex or harmful than semi-structured interviews, it is important for the researcher to be aware of basic principles for protecting the respondents, including full disclosure and consent. For example, in survey research, each respondent should be fully informed as to the purpose of the study, confidentiality of responses, how the results are intended to be used, and who will have access to the data. Bacon and Olsen (2005) also indicate that survey researchers have the ethical responsibility of not wasting a respondent’s time and to only collect data that has utility.

In addition to the ethics approval, an ‘informed consent’ form was stipulated by the university and was sent to all the participants to sign before they engaged in research. This form acknowledges that participants’ rights will be protected during data collection. Elements of the informed consent form include the following:

- Identification of the researcher
- Identification of the sponsoring institution
- Indication of how participants were selected
- Identification of the purpose of the research
- Identification of the benefits for participating
- Identification of the level and type of participant involvement
- Notation of risks to the participant
- Guarantee of confidentiality to the participant
- Assurance that the participant can withdraw at any time
- Provision of names of persons to contact if questions arise

5.7 SUMMARY OF CHAPTER 5

This chapter discussed the methodology used for the research. It provided an overview of the methodological process comprising of literature review, conceptual framework, the research approach and the validation of framework. It examined different research approaches and their underlying philosophical assumptions. It explored different research designs or strategies of inquiry available for research including methods for data collection and analysis. It discussed the selection and justification of the research approach, research design and research methods for this study. The chapter also discussed the sampling strategies and ethical issues considered for the research.

CHAPTER 6

QUALITATIVE STUDY ON THE IMPACT OF KNOWLEDGE MANAGEMENT ON THE COST OF POOR QUALITY

This chapter discusses the results from the qualitative study on the impact of knowledge management on the cost of poor quality. It presents the profile of the interviewees involved in the study. It discusses the findings on the contributory factors to the cost of poor quality in practice which includes the cost of errors and omissions, cost of design changes and the cost of poor skills. The chapter discusses the findings on the impact of knowledge management on these costs. It presents and discusses the findings on the optimisation of knowledge management to reduce the cost of poor quality on construction projects. The chapter also presents a modified conceptual framework and draws conclusions on the qualitative study.

6.1 PROFILE OF INTERVIEWEES

The interviewees were selected from industry communities of practice and expert forums across UK based on eligibility criteria which included project experience, organisational experience and job designation (see Table 6.1). The interviewees have acquired years of experience in large construction organisations (over 250 employees) in the supply chain. All of the interviewees have worked with main contractors, and have been involved in a diverse range of projects. Although the UK construction industry is made up mostly of small and medium sized organisations (up to 250 employees), large organisations particularly the main contractors undertaking large projects tend to engage several of these smaller organisations in their supply chain (BIS 2013).

Table 6. 1: Profile of interviewees

Interviewee ID	Years of experience	Project experience*	Organisation experience*	Current designation
A	40	1, 2, 3, 4, 5, 6	1, 2, 3, 5, 8	Director/continuous improvement
B	35	1, 6	1, 2, 3, 4, 8	Director/architecture
C	33	1, 2, 4, 6	1, 2, 3, 4, 7	Supply chain manager
D	32	1, 6	1, 2, 3, 7	Senior consultant/strategy innovation
E	30	1	1, 2, 3, 5	Director/supply chain knowledge management
F	30	1	1, 2, 3	Director/technology
G	30	1, 2	1, 2, 3	Director/performance improvement
H	29	4	3, 4	Project design engineer
I	25	1	1, 2, 3	Cost consultant
J	23	1, 2, 3	1, 2, 3	Director/knowledge management
K	23	1, 2, 4	2, 3, 6	Director/operations
L	15	2	2, 3	Site engineer
M	14	4	2, 3, 4, 5	Project engineer
N	14	1, 2, 3, 4, 5	2, 3, 5	Projects control manager
O	14	4	2, 3, 5	Project risk engineer
P	12	1	3, 5	Project manager
Q	12	4	3, 4	Senior design engineer
R	10	1, 2	2, 3	Change manager/ knowledge management
S	10	4	3, 4	Project design engineer
T	8	5	1, 3	Project engineer
U	8	2	3	Site surveyor
V	8	5	1, 3	Engineer/water
W	7	1	3	Senior quantity surveyor
X	6	4	3	Design engineer
Y	6	4	3	Design engineer

*Key

Project experience	Organisation experience
1 – Building construction	1 – Client organisation
2 – Highways	2 – Consultancy
3 – Rail	3 – Main contractor
4 – Utility (power)	4 – Design organisation
5 – Utility (water)	5 – Project management
6 – Other	6 – Sub-contractor
	7 – Supplier
	8 – Other

The study therefore adopted a top-down approach by selecting interviewees from the main contractor organisations. Interviewee job levels were categorised into either ‘managerial’ or ‘operational’ to allow for variation and comparison of perspectives (see Table 6.2). Thirteen (13) of the interviewee job levels were managerial while twelve (12) of them were operational. This represents 52% and 48% of total interviewees respectively.

Table 6. 2: Job level of interviewees

Job level	**No of interviewees**
Managerial	13
Operational	12
Total	25

The years of experience of interviewees ranged from just over five (5) years to over thirty (30) years (Table 6.3). This allowed for a wide distribution of years of experiences which positively influenced the variation of responses from interviewees.

Table 6. 3: Years of experience of interviewees

Years of experience	**No of interviewees**
>30	4
>20 ≤ 30	7
>10 ≤ 20	6
>5 ≤ 10	8
Total	25

Interviewees have acquired a variety of experiences from different sectors in the construction industry (Table 6.4). Majority of the interviewees (56%) have worked in building construction, 44% have worked in utility (power) while 36% have worked in the highway sector. 16% of the interviewees have worked in utility (water) while 12% have worked in the rail sector.

Table 6. 4: Project experience of interviewees

	Project experience	**No of interviewees**	**% of Interviewees**
1.	Buildings	14	56%
2.	Highways	9	36%
3.	Rail	3	12%
4.	Utility (power)	11	44%
5.	Utility (water)	4	16%
6.	Other	4	16%

Interviewees not only possessed various project experiences but also various organisational experiences (Table 6.5). All of the interviewees have worked for main contractors at various stages of their work experience. 44% of the interviewees have worked for client organisations, 36% for consultancies, 24% have each worked for design organisations and project management organisations. Few of the interviewees (4%) have worked with sub-contractors. It was important however that all of them worked with main contractors as they form the core of the investigation on the impact of KM on COPQ.

Table 6. 5: Organisational experience of interviewees

	Organisational experience	**No of interviewees**	**% of interviewees**
1.	Client organisation	11	44%
2.	Consultancy	9	36%
3.	Main contractor	25	100%
4.	Design organisation	6	24%
5.	Project management	6	24%
6.	Sub-contractor	1	4%
7.	Supplier	2	8%
8.	Other	2	8%

Despite the current job designation of the interviewees, their main areas of expertise were found to be in knowledge management, quality management, cost management, project management and design management (Table 6.6). Seven (7) interviewees are experts in knowledge management, six (6) each in project management and design management, four (4) in quality management and two (2) in cost management.

Table 6. 6: Areas of expertise of interviewees

Areas of expertise	No of interviewees	Interviewee ID	% of interviewees
Knowledge management	7	A, C, D, E, G, J, R	28%
Quality management	4	F, K, N, O	16%
Cost management	2	I, W	8%
Project management	6	L, M, P, T, U, V	24%
Design management	6	B, H, Q, S, X, Y	24%

The expertise of the interviewees is not limited to one type of project or organisation. What they all have in common however is that they have worked for main contractors and have all been involved in industry-wide KM initiatives. The research methodology has been discussed in Chapter 5. This chapter discusses the results.

6.2 CONTRIBUTORY FACTORS TO THE COST OF POOR QUALITY

The findings presented in this section are based on the interviewee responses to the interview questions from Section B of the interview questions template (Appendix 4). The questions were as follows:

(1) From your experience of construction projects, what are the contributory factors to the cost of errors and omissions on projects? (2) What are the contributory factors to the cost of design changes during projects? (3) What are the contributory factors to the cost of poor skills on projects? The interview data analysis was discussed in section 5.4.1. The sample coding for the data are shown in Table 5.2.2 and 5.2.3 under sub-section 5.4.4.4. The findings were based on recurrent themes and commonality of responses across all interviewees. This enables the identification of factors that are widespread and

cut across all project types. The contributory factors to COPQ are discussed in the next three sub-sections.

6.2.1 Contributory factors to the cost of errors and omissions

The cost of errors and omissions include costs associated with erroneous construction methods and procedures, and omissions of construction activities. Errors and omissions were found mostly within the construction phase of projects which usually involved the activities of the main contractor and how they manage their sub-contractors. According to Interviewee B, "It's usually a contractor problem, my suggestion is how they should be controlling the workforce better so that these things don't happen…". The themes that emerged from the coding of the interview data are: rule-based mistakes; knowledge based mistakes; slips and lapses of attention; lack of lessons learnt; habits; organisational culture; time constraints; budget constraints; poor communication; procurement strategy; design issues; and construction product issues.

6.2.1.1 Rule-based mistakes

Rule-based mistakes arise from selecting a wrong solution to a problem. These are actions that match intentions but do not achieve their intended outcome due to incorrect application of a rule or inadequacy of the plan. Rule-based mistakes involve utilising old methods for new challenges. An example of this was described by one of the interviewees in which a particular rule applied on a utility (power) project was attempted on a similar and new project but was due to fail.

> *"… we've got a project that we are working and it's a prototype of what's being delivered in France so our assumption was that we were going to take the design from France and execute it in the UK but along the line we got to realised that the building regulations over here is not making the design from France work … if we had progressed to deliver it we would have had a lot of issues with construction at the end of the day"* – Interviewee N

6.2.1.2 Knowledge based mistakes

Knowledge-based mistakes arise from insufficient knowledge about how to perform a task. This results in the development of a solution that is incorrectly expected to work. Personnel are usually faced with this problem when working with new concepts, unfamiliar designs or construction processes.

> *"Basically I will say that some of the challenges we faced on that project (building project) was that some of these concepts that were not well thought through and was not totally based on previous design it was a great departure from well known design"* – Interviewee M

In this particular case, the sequence of work was not entirely understood. This led to project delays, errors and additional costs.

6.2.1.3 Slips and lapses of attention

This type of error occurs at the point of task execution, and includes actions performed by unintentionally skipping or reordering a step in a procedure, performing the right action on the wrong object**,** or performing the wrong action on the right object.

6.2.1.4 Lack of lessons learnt

This relates to the repetition of mistakes due to lack of learning from past experiences or trying to 're-invent the wheel'. Lack of lessons learnt is one of the most common contributors to the cost of errors and can sometimes lead to unquantifiable costs such as fatalities. Two examples of this were given by one of the interviewees who worked on a highway project. One of the examples involved fatalities as a result of lack of lessons learnt.

> *"I started hearing things like…a mini digger had fallen over on site causing somebody injury obviously causing the impact on the work…then a few weeks later I heard another mini-digger had fallen over on another site and I just thought why are we not learning from each other basically the incline they were using was too steep for this particular mini-digger so its common sense really but why havn't we learnt from the first thing happening and why is it happening again"* – Interviewee R

> *"Lack of lessons learnt can lead to fatalities. Two people died while I was there..(motorist fatalities due to company's errorneous placement of cones)… and that happened twice while I was there in five years… but we didn't learn the first time"* – Interviewee R

6.2.1.5 Habits

Habits relate to the routine of behaviour that is repeated regularly and tends to occur unconsciously, sometimes negative. The negative habits that were identified during the interviews include; site personnel trying to cut corners, laziness, and general non-compliance with guidelines.

6.2.1.6 Organisational culture

This represents the collective values, beliefs and principles of organisational personnel which can sometimes be adversarial. This includes blame culture in which personnel point the ‘finger of blame’ in an adversarial way, which in effect reduces innovation potential. Knowledge hoarding was also identified as an embedded in certain organisational culture in which personnel are reluctant to share their knowledge in order not to lose their competitive advantage.

6.2.1.7 Time constraints

Time constraints were identified as a significant factor contributing to the cost or errors and omissions. Interviewees suggested that personnel are bound to commit errors if they are under time pressure. An example was given by one of the interviewees who worked on a highway project.

> *“While taking levels, the benchmark was moved, the staff was read upside down. Consequently an error of up to one metre was transferred to all the levels and that cost us thousands of pounds. Everybody makes mistakes you know… I don’t care if you have five years experience if somebody is rushing you, if you are under pressure you must make a mistake ...”* – Interviewee U

6.2.1.8 Budget constraints

Margins were being squeezed by low bidding and excessive competition encouraged by clients, leading to shortage of resources to do good quality jobs. Lowest bidding usually lead to ‘penny wise pound foolish’ syndrome in which incompetent contractors are unknowingly hired and end up costing more in errors or damages in the course of the project.

> *"People (clients) hack down the price and then expecting better value …and you know what happens is the cheaper price looks very nice on paper, you accept it you go with it, the guy that gives you the cheaper price hasn't got the means… business is not well supported and probably doesn't have the right level of health and safety, quality control, quality assurance and what ends up happening is these guys get spread too thinly and they then can't do the job they then become quite unproductive they then lose money they then go out of business"* – Interviewee K

6.2.1.9 Poor communication

This includes poor information flow on-site, poor definition of tasks, language barrier and so on. While poor communication within the project team can increase costs associated with errors, good communication at all levels can lead to innovation and better technical solutions.

6.2.1.10 Procurement strategy

Errors were found more likely to occur on projects adopting procurement strategies that are less favourable to collaboration and knowledge sharing among supply chain.

6.2.1.11 Design issues

Errors on site can result from design issues from the drawing office. A relevant example was given by one of the interviewees working on a utility (power) project.

> *"There is a project where they did everything before doing site investigation and because they didn't do the site investigation they had many problems on site and also because of steel structure design was*

> *wrong, they had faulty steel manufactured members. When they took these members to the site for installation they didn't fit and it was too late and they had to do everything from the beginning and they lost loads of time. According to the contract, it was the full responsibility of (the company) to provide the correct design and on time"* – Interviewee S

6.2.1.12 Construction product issues

Multiplicity of new construction products and interfaces create installation challenges on site thereby leading to errors. Sub-standard and defective products also contribute to these errors. Personnel in these cases do not understand how the products worked which results in workmanship issues. The use of cheap materials also contributes to errors.

> *"Sometimes it is poor products, poor design, sometimes poor workmanship, sometimes it is the unexpected consequences of materials not working very well"* – Interviewee D

Table 6. 7: Summary of the contributory factors to the cost of error and omissions

Contributory factors to the cost of errors and omissions	Description
Rule-based mistakes	Selecting a wrong solution to a problem. These are actions that match intentions but do not achieve their intended outcome due to incorrect application of a rule or inadequacy of the plan.
Knowledge based mistakes	Insufficient knowledge about how to perform a task results in the development of a solution that is incorrectly expected to work
Slips and lapses of attention	Error occurs at the point of task execution, and includes actions performed by unintentionally skipping or reordering a step in a procedure, performing the right action on the wrong object, or performing the wrong action on the right object
Lack of lessons learnt	Repetition of mistakes due to lack of learning from past experiences
Habits	Routine of behaviour that is repeated regularly and tends to occur unconsciously, sometimes negative e.g. trying to cut corners, laziness, non-compliance
Organisational culture	Represents the collective values, beliefs and principles of organisational personnel which can sometimes adversarial e.g. blame culture, knowledge hoarding.
Time constraints	The notion that projects are time constrained therefore workers are bound to commit errors under time pressure
Budget constraints	Margins being squeezed by low bidding and excessive competition encouraged by clients, leading to shortage of resources to do good quality jobs.
Poor communication	This includes poor information flow on-site, poor definition of tasks, language barrier etc.
Procurement strategy	Errors are more likely to occur on projects adopting procurement strategies that are less favourable to collaboration and knowledge sharing among supply chain.
Design issues	Transference of errors from design to construction
Construction product issues	Multiplicity of new construction products and interfaces create installation challenges on site thereby leading to errors. Sub-standard, and defective products also contribute to errors

6.2.2 Contributory factors to the cost of design changes

Design changes include design revisions, modifications and improvements during the design and construction phase of a project. There is a level of tolerance for design changes during the design phase; however, frequent changes during the construction phase constitute additional unnecessary costs in rework. The focus therefore is on the design changes that occur during the construction phase. It was found that changes were mostly initiated by the client and sometimes by other organisations in the supply chain e.g. the main contractor, the architect or the structural engineer. There was a notion that design change is inevitable and that design is an iterative process in which provision has to be made for. According to Interviewee E, “design changes are mainly due to client changes. For example during the construction of (building name), the client suddenly wants a swimming pool on the 40th floor. This cost a lot of money and time. There will always be design changes during the life of a project. It keeps changing and nothing can be done about it…” Other contributory factors to design changes were found to be: unforeseen site conditions; poor communication among supply chain; poor client expertise; constructability issues; errors and omissions on site; procurement strategy; time constraints; and budget constraints.

6.2.2.1 Client/end-user change

Most changes that occur during construction projects are initiated by the client or the end-user. Client usually request changes to product requirement, project definition or project scope. This has significant effect on the cost of poor quality. A few of the experiences relating to client change are described by the interviewees.

> *“The project (building project) was challenging, we didn’t deliver to time, we didn’t deliver to budget. Why was that? The reason was an unclear definition what the requirements were by the client. There was a lower level involvement of the business in the definition of the project initially”* – Interviewee C

> *“I’ve come across a number of design changes, some of these changes do come due to client requests, clients changing their minds on what*

they want or what they don't want. Those are changes we still try to manage within the design phase" – Interviewee O

"Some clients just think oh well I'm paying the bills I can change my mind whenever I want, still get it done on time and on price and everything, that's when you run into trouble on these big and complex projects". – Interviewee I

6.2.2.2 Other changes

Other changes are initiated by the contractor, the architect, structural engineer and even external stakeholders who are not part of the project team. They usually make request to change product requirement and definition, project scope or construction process. The contractor for example may request design change as a result constructability issues. In the case of external stakeholder change, according to Interviewee X, *"…change can occur due to building regulations"*

6.2.2.3 Design change inevitable

In construction project management, there is a general perception that design is an iterative process, and is bound to change throughout the construction phase. In other words, design evolves in the course of the project therefore the contract should make provision for this.

"Design change is normal in certain types of contract. Design and build contract allows for the design to evolve during the duration of the contractual period" – Interviewee J

> *"Some changes are needed really because of the evolution of the design in generalities obviously some changes occur because the client physically changes his mind and the key thing to me with regard to changes which are inevitable, it's going to actually happen"*
>
> – Interviewee D

6.2.2.4 Unforeseen site conditions

Unforeseen site conditions were found to contribute to design changes and associated costs. This includes unforeseen ground conditions, inclement weather, location of utilities underground etc. this situation is usually brought about by lack of thorough site investigation, or lack of time to conduct the investigations.

> *"I'll pick on an instance, we have got a substation to connect (with transmission lines), it's a brand new substation. You are not always able at the beginning of the scheme to basically fix the interface between you, the ovehead line and also the substation so when the substation people finally get on site and its not exactly a flat site, but they've got to cut and fill with their big bulldozers so you start to see the levels going up and down and things moving that means we have to basically going back and revisit the design"* – Interviewee H

> *"There is a project where they did everything before doing site investigation and because they didn't do the site investigation they had many problems on site and also because the steel structure design was wrong, they had faulty steel manufactured members. When they took these members to the site for installation they didn't fit and it was too*

late. They had to do everything from the beginning and they lost loads of time and money" – Interviewee S

6.2.2.5 Poor communication

Poor communication among project team was found to be a recurrent contributor to the cost of design changes. This includes poor communication of client need to the designer or poor communication between the designer and the contractor. Poor communication can come as a result of lack of flow of design information, poor document control, unclear definition of client requirement or even language barrier among personnel.

> *"Certainly they (clients) are not experts in contruction, they don't know the language, they don't know what they want, and when you actually give it to them they realise its not what they want, so I think that possibly the greatest problem is actually communicating effectively with the client"* – Interviewee B

> *"...the problem really was lack of communication because the construction site was in Scotland and project team was there but the design team, they are in India and the manufacturing company is in Turkey. So management could not coordinate all these three groups. India didn't get the up to date information from site and prepare the design on all the information and the design went to the manufacturing company and the members were manufactured according to the wrong design and they were shipped to scotland" – Interviewee S*

6.2.2.6 Poor client expertise

Clients are not necessarily experts in construction, the costs associated to design changes can also be attributed to this factor. Clients sometimes do not fully understand the implications of design and construction scope changes particularly quality implications, time implications, and cost implications.

6.2.2.7 Constructability issues

The learning curve is usually steep when experimenting with non-conventional designs or never-before-tested concepts. There is bound to be design changes in the course of these types of projects. Architects sometimes lack adequate construction experience therefore producing impracticable or incompatible designs. Multiple examples were cited by interviewees, two of which were presented below.

> *"Our mega projects where you've got multiple components multiple systems coming in, if you miss one, you've got a potential 6 months delay on the project and you could be running into substantial capital costs to fix the problem so dimensional control is always a challenge as well as interface control"* – Interviewee O

> *"Just because it works on paper doesn't mean it works in reality. It's lack of knowledge and poor skills but it is also because we have such a plethora of materials to chose from so it's hard to know how every interface with new products materials work together"* – Interviewee G

6.2.2.8 Errors and omissions on site

Sometimes construction errors committed on site can lead to a change or modification of existing design to accommodate the errors. This may seem unprofessional but it is often practiced.

> *"The one that actually stands out in my mind is foundation design for a particular tower. The orientation on the design was ok but on site they didn't place the foundation very well so the tower was out of place and would not sit on the foundation so we had to tink round our design and do some reconstruction both on site and work our design to make the tower fit on the foundation" – Interviewe Q*

6.2.2.9 Procurement strategy

The choice of procurement strategy or contract type can influence the cost performance of a project. It was found that some of the procurement strategies did not facilitate early involvement and collaboration of supply chain in contributing to the design phase of a project. It was also found that some procurement strategies did not support design innovation.

> *"It all depends on the procurement process because some procurement processes do not allow for design innovation to happen. If you are using a fast track approach to construction where you almost started on site before the designs are completed and as the construction is commencing you are actually desinging the project"* – Interviewee J

> *"If you can get all the parties involved to buy in from the design stage all the way through the project, you sort of eliminate stupidity waste"* – Interviewee I

6.2.2.10 Time constraints

Time pressure to commence construction quickly can imply that in-adequate time is spent on design and planning. It is very common in the construction industry to rush to commence work on site before the design stage is thoroughly reviewed.

> *"I would say as for jobs originally being scoped out correctly or in sufficient detail, it is easier for the contractor to correctly tender for that work…but has the contractor during its tendering process put sufficient time and resourcing to identify all the work that is required? The other one comes from the client to give you sufficient time before you are expected to be on site to build…"* – Interviewee H

> *"Where the client, architect, engineers or project management people didn't get their end sorted by the time the contractor was appointed, it just became a battle throughout the actual construction stage. There is sort of design as you go mentality"* – Interviewee I

6.2.2.11 Budget constraints

Not designing to cost from inception leads to future design changes e.g. scaling down scope of work.

"We design to cost so actually the client gets the bespoke building they want for the price they can afford. Designers should be made to design to cost from the onset so they build in products and materials that are appropriate to cost that the client can afford so you build it up using the correct components" – Interviewee G

Table 6. 8: Summary of the contributory factors to the cost of design changes

Contributory factors to the cost of design changes	**Description**
Client/end user change	Client/end-user change to product requirement, definition and project scope
Other changes	Initiated by contractor, architect, structural engineer etc. to change product requirement and definition, project scope or construction process
Design change inevitable	Perception that design is an iterative process, and is bound to change throughout the construction phase.
Unforeseen site conditions	E.g. unforeseen ground conditions, inclement weather, location of utilities etc.
Poor communication	E.g. of client need to the architect, between architect and contractor or between other supply chain organisations
Poor client expertise	E.g. not understanding design/construction scope and cost implications, balance between scope, cost, time and quality.
Constructability issues	Learning curve is often steep when experimenting with non-conventional designs or never-before-tested concepts. There is bound to be changes in the course of the project. Architects sometimes lack adequate construction experience therefore producing almost inconstructable designs
Errors and omissions on site	Non-reversible errors and omissions on site can lead to review and modification of existing design
Procurement strategy	Procurement strategies that do not facilitate early involvement and collaboration of supply chain to contribute to the design phase of a project. Procurement strategies that do not support design innovation.
Time constraints	Time pressure to commence construction quickly can imply that in-adequate time is spent on design and planning. Rush to get on site before design stage is thoroughly reviewed
Budget constraints	Not designing to cost from inception leads to future changes e.g. scaling down scope of work

6.2.3 Contributory factors to the cost of poor skills

It was found that, within the construction phase of a project, poor skills mostly affected the main contractor and sub-contractors across management and operational levels. Inadequate knowledge of processes and procedures, poor planning and scheduling, poor workmanship were some of the effects. Apart from contractor skills, examples were found for poor designer or architect skills.

> *"Its only when you are actually working on the site where you can see the impact of the way people assemble buildings or assemble components*

> *safely in that environment, it automatically changes the framework of the way that you think, people (designers) who have not got that experience tend to say I just designed it, I'm not a skilled installer or erector of these things that's the contractors problem or issue so there is a lack of holistic thinking that sometimes goes on with regards to designer who does design individual components"* – Interviewee D

> *'One of the things we are finding is actually a lot of architects don't know how to specify. What they are actually specifying is incorrect and it's the buildability and the experience of our guys (building contractor personnel) challenging them to say that's not right or it shouldn't be done like that or…the way you showed the tiles…or where you showed the damp proof is wrong…and working in the firm to get it right'*
> – Interviewee G

The contributory factors to the costs of poor skills were identified as: high personnel turnover; lack of training; lack of dedication; complacency; time constraints; budget constraints; project based nature of the industry; and organisational culture.

6.2.3.1 High personnel turnover

Uncertainties associated with winning new work by supply chain organisations often lead to a cycle of redundancies and re-recruitment. The widespread use of temporary workers prevents the capture and retention of knowledge within organisations. There is also a difficulty in attracting and retaining younger workforce. Unfortunately the construction industry is heavily reliant on experience which is only built over a long period of time. The inability to retain personnel therefore contributes immensely to the costs associated with poor skills in construction.

> *"In this industry, they come and they go out very fast. Money is another issue as well for construction people and a lot of these young people think the job is going to be easy, so the graduates when they come in they do like office work not outside work, they are not very exposed and are not getting proper guidance from the senior engineers"*
> – Interviewee L

6.2.3.2 Lack of training

There was a consensus among all the interviewees that the industry lacks adequate training construction personnel.

> *"The problem with the industry at the moment is the trades people because of the constant ups and downs in the industry we just don't train enough quality trades people anymore sort of plumbing electrical systems even in like domestic build, getting ever and ever more complex"* – Interviewee I

6.2.3.3 Lack of dedication

There is lack of dedication to work especially among younger people, majority of which are not willing to stay in the industry on the long run.

> *"Probably its happening everywhere, things like lack of communication probably they (senior personnel) feel that the youngsters coming into the industry are not going to be there for very long, some of them come in and go out, some of them just come because of the salary, some of them*

> *come because of the benefit, some of them come to learn for a short period and move on"* – Interviewee L

6.2.3.4 Complacency

Complacency relates to the attitudes of personnel and their unwillingness to learn new things or be criticised.

> *"Some of our staff they've got big attitude you know you've been there so long and they know the job, sometimes they don't do their jobs (properly) so we address their seniors and their seniors will always, talk to them and get everything rectified"* – Interviewee L

6.2.3.5 Time constraints

Perceived time pressure prevents organisations from investing time to train personnel and to transfer knowledge from experienced personnel to less experienced ones poor time keeping.

6.2.3.6 Budget constraints

Budget constraints often leave little provision for apprenticeships and mentoring opportunities as well as sourcing for the right personnel for construction projects. Examples are cited from the interviews:

> *"It started from the tender team and the project management team, they didn't want to spend money to help source for or staff the job properly really. So its management really, it was their fault*" – Interviewee U

> *"I started to monitor my colleagues on how long things were taking and then comparing that with how long we had priced in estimate to do the job and then very quickly we begin to realise that we estimate something*

> *to take so long but in reality it takes a lot longer so that then creates an overspend of labour costs against what you are estimating for. If the whole business takes longer than it takes in the estimates in your bids, you quickly go out of business"* – Interviewee K

6.2.3.7 Project based nature of industry

It is challenging for organisations to make long term commitments to skills development due to the short term project based nature of the industry.

6.2.3.8 Organisational culture

Adversarial organisational culture has impact on skills in several ways which include in-adequate knowledge sharing by project personnel and non trasferrence of knowledge or vital skills from experienced personnel to less experienced ones. Furthermore there was evidence of disconnect between experienced personnel and junior ones.

> *"We had a bridge that collapsed which we are supposed to get our juniors to go out. We've got team of inspectors who've been there for 30 odd years never passed on the skills to youngsters or to the juniors so I think that the the seniors are not passing down their knowledge or their experience to the juniors"*– Interviewee L

Table 6. 9: Summary of the contributory factors to the cost of poor skills

Contributory factors to the cost of poor skills	**Description**
High personnel turnover	Uncertainties associated with winning new work often lead to a cycle of redundancies and recruitment. Widespread use of temporary workers prevents the capture and retention of knowledge within organisations. There is a difficulty in attracting and retaining younger workforce
Lack of training	Industry lacks adequate training construction personnel.
Lack of dedication	Lack of dedication to work especially among younger people, majority of which are not willing to stay in the industry on the long run.
Complacency	Complacency relates to the attitudes of personnel and their unwillingness to learn new things or be criticised
Time constraints	Percieved time pressure prevents organisations from investing time to train personnel and to transfer knowledge from experienced personnel to less experienced ones
Budget constraints	Budget constraints leaves little provision for apprenticeships and mentoring opportunities
Project based nature of the industry.	It is challenging for organisations to make long term commitments to skills development due to the short term project based nature of the industry.
Organisational culture	In-adequate knowledge sharing and knowledge transfer culture among project personnel

6.2.4 Discussion of findings on the contributory factors

It was found that projects are still plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to unnecessary cost of re-doing processes incorrectly implemented the first time. The findings support previous work by Al-Ghassani et al., 2004; Egbu, 2005; Suresh et al., 2008; Carrillo et al., 2013; and Ren et al., 2013. The constituent elements of COPQ were found to be the cost of errors and omissions, the cost of design changes, and the cost of poor skills which support Feigenbaum, 1986; Juran and Godfrey, 1998; Josephson and Hammarlund, 1999; Love and Edwards 2005; and Rosenfeld, 2009. Out of the contributory factors to COPQ, twelve (12) were found to contribute to the cost of errors and omissions, eleven (11) to the cost of design changes and eight (8) to the cost of poor skills. These are represented in the diagram in Figure 6.1. There were commonalities found within the contributory factors. Organisational culture was found to be common with errors and omissions, and poor skills. Procurement strategy and poor communication was found to be common with errors and omissions, and design changes. Time constraints and budget constraints were found to contribute to all three constituent elements of COPQ. Considering the commonalties and overlaps, this brings the total contributory factors to twenty four.

Causal links were found between the COPQ factors contrary to the theoretical suggestion of being mutually exclusive. This is represented by the arrow links shown in the diagram in Figure 6.1. Errors and omissions for example can be caused by poor skills; errors and omissions on site can be caused by design issues; design changes can be caused by irreversible errors on site, or by poor skills of the designers. COPQ therefore requires an inclusive and holistic approach to addressing the problem.

Nevertheless the findings confirm the prevalent project challenges faced by supply chain organisations in the project context such as time constraints, tight schedules and limited budgets (Zin and Egbu 2011, Ruan et al. 2012). Surprisingly, it was found that COPQ can be profitable to the contractor depending on the procurement strategy or contract type particularly if the contractor was not involved in the design stages of the project. Any form of design changes or rework can therefore benefit the contractor. This can be profitable to the sub-contractors and suppliers as they would have more paid work.

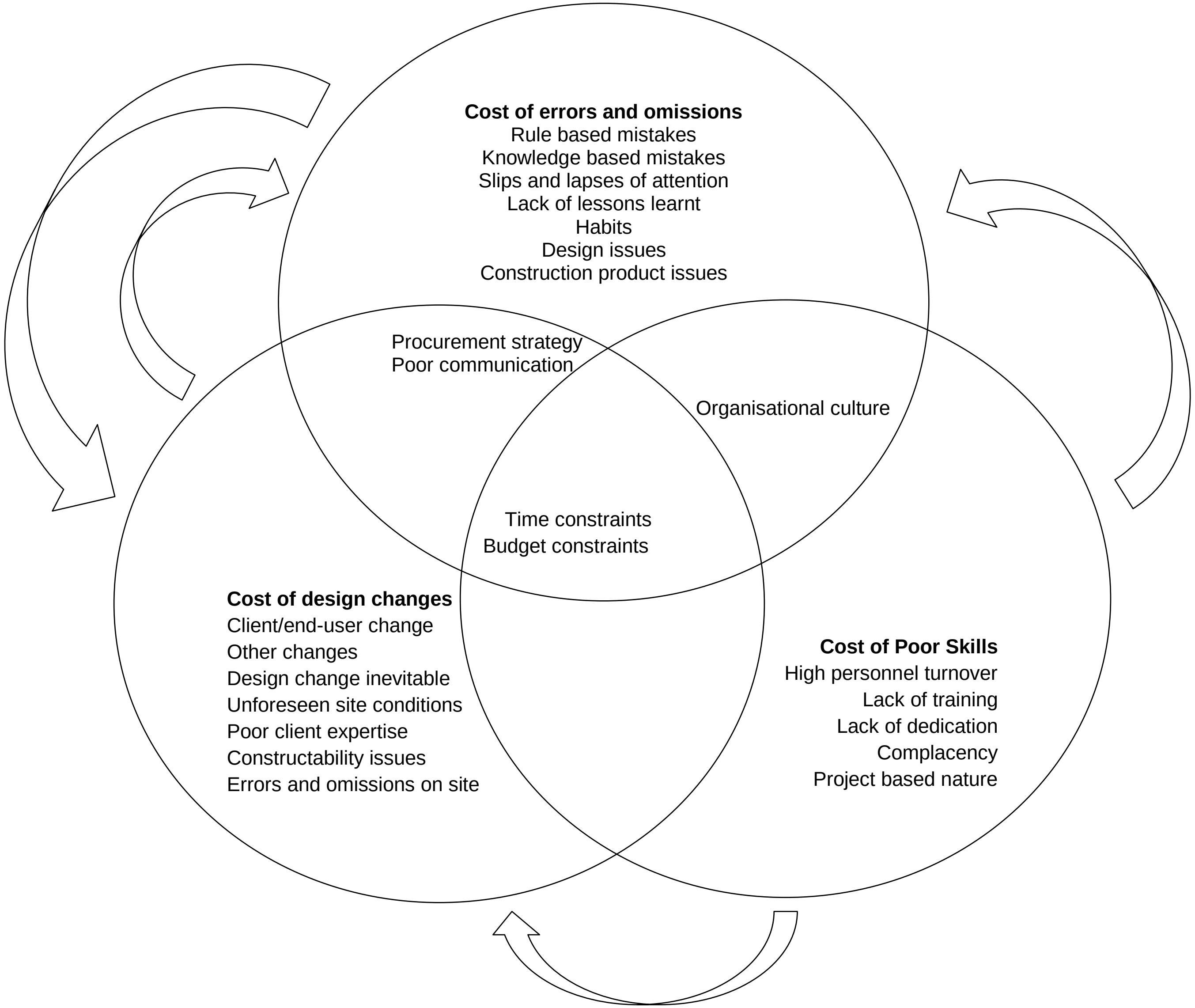


Figure 6. 1: Contributory factors to COPQ in practice

COPQ can also be profitable to the designer in the case of client's decision to change the design specification or the scope of work. Two examples are cited below:

> *"You can make a fortune out of bad design. For the contractor bad design is good right? Yeah, if you have a good sight to recognise these things, delays delays delays and compensation"* – Interviewee U

> *"If you are a construction company and don't get involved in the design and you are a contractor, the cost of change can be very good. I worked for construction companies that when we won the contract we knew that the client has selected the wrong form of contract. If the contract is right, the cost of change will benefit who has to do this work. So is there a cost of change to the client or is it an opportunity of more profit for the contractor so it all depends on the type of contract you are under"*
> – Interviewee J

However, in most instances supply chain organisations are responsible for their own 'faults'. For example, the contractor is responsible for errors and omissions on site while the client is responsible for any client changes and so on. An example of a utility (power) project in which the contractor had to pay is cited below.

> *"They (client) were not happy with it. What happened was that on that scheme we didn't make any profit we worked at a loss because we didn't finish on time, we lost the incentive on it and because we missed out on the (power) outage, we lost a lot of money because someone had*

to pay for everyday that the line was down we paid significant amount to people generating the elecrticity" – Interviewee Q

The rationale and the focus of this study is on reducing COPQ thereby increasing profitability of all the organisations working on a project rather than for one organisation to make gains to the detriment of another organisation on the same project.

6.3 IMPACT OF KNOWLEDGE MANAGEMENT ON THE COST OF POOR QUALITY

The findings presented here are based on Section C of the interview template (Appendix 4). The main questions asked the interviewees are stated as follows: Which knowledge management initiatives were in place on the projects you worked on? How did the initiatives impact the reduction of errors and omissions? How did the initiatives impact the reduction of design changes? How did the initiatives impact the reduction of poor skills? The findings were derived from the coding of the interview data (Section 5.4.4.4) and are discussed in the next three sections.

6.3.1 Impact of knowledge management on the cost of errors and omissions

KM was found to have positive impact in reducing rule-based mistakes, knowledge based mistakes, lack of lessons learnt, poor communication, and construction product issues. There was evidence of knowledge sharing across personal, organisational and project levels. Across personal level for example, Interviewee D stated that "we do encourage teamwork for all areas of our work. We ensure that we have experts who share their knowledge with the rest of the team so that not only one person knows one thing but several people and these people meet every time in order to keep that knowledge in the company". In the case of Interviewee L, "the company do have toolbox talks. Every month each employee has to come up with a toolbox talk. For example if I pick up a defect that nobody knows or I pick up a very scientific name or something that I learned throughout my experience, I'll give a talk of the month. I exchange my knowledge in a toolbox talk". At organisational level, Interviewee G stated that "we have the knowledge bank, we have technical excellence groups.

The technical excellence group reviews the knowledge and the problems and everything that come up and decide what is in our core processes and systems we have to change to make sure that wouldn't happen again, and then we have a number of publications which we produce that goes through the main functions and operations" Another example was from Interviewee Q who stated that "we have lessons learnt in place and we keep records. They are all documents but we have a way of putting everything online because immediately it (issues) happens on site you have to write it down in your technical query log and from that log book we transfer it to lessons learnt once the whole scheme is finished".

At project level, Interviewee E stated that "we ensure that we retain most of our supply chain of about 60 companies and use them from project to project. The benefit of this is that significant project knowledge is retained within the chain there is a level of trust within the chain since they are rest assured that they will be working together for a long time. The environment of trust therefore encourages knowledge sharing among parties" Little evidence was found on industry level KM initiatives. Overall KM has less impact in reducing slips and lapses of attention, habits, organisational culture, time constraints, budget constraints, choice of procurement strategy, and erroneous designs carried over into the construction phase.

6.3.2 Impact of knowledge management on the cost of design changes

KM was found to have most impact on the cost of design changes at organisational and project levels. Despite the notion that design change is inevitable during the construction phase of a project, it was found that KM had impact in reducing client and other supply chain changes, poor communication, poor client expertise, constructability issues, site related errors and omissions. Although Interviewee E stated that; “design is an iterative process therefore change is inevitable”, it was found that early involvement and collaboration among supply chain had positive impact in reducing the cost of design changes.

Interviewee H commented that “there are existing contracts with our client, they were bringing the (sub) contractors in during the development stage of the job at the feasibility stage and that does help out enormously cause they probably get the right skill level and experience to identify all the work thats required for that paricular project… that does have cost implications”. Similarly Interviewee I commented that “If you can get all the parties involved to buy in from the design stage all the way through the project, you sort of eliminate stupidity waste” KM was found to have less impact on procurement strategy, time constraints and budget constraints. The choice of procurement strategy however has impact on KM. Organisations in the supply chain particularly the contractor stands to gain from design changes therefore would prefer continuous changes on projects to increase profit margin. Interviewee U noted that “you can make a fortune out of bad design. For the contractor bad design is good right? Yeah, if you have a good sight to recognise these things, delays delays delays and compensation”. Interviewee J similarly stated that “If you are a construction company and don’t get involved in the design, the cost of change can be very good. I worked for construction companies that when we won the contract we knew that the client has selected the wrong form of contract. If the contract is right, the cost of change will benefit who has to do this work. So is there a cost of change to the client or is it an opportunity of more profit for the contractor so it all depends on the type of contract you are under”.

6.3.3 Impact of knowledge management on the cost of poor skills

It was found that KM has low impact in reducing high staff turnover however it has strong impact in reducing the knowledge vacuum created by it. There was evidence of knowledge sharing and knowledge transfer through mentoring in order to retain knowledge of experienced staff and to improve the skills of the less experienced ones. Interviewee O commented that “we’ve got mentoring system, we’ve got line management system, we’ve got what is called functional and their delivery line management system which is like dual role on its own so that kinds of reduce the impact of knowledge erosion or knowledge loss” Similarly Interviewee D commented that “people always work together in a group basically for every position you find out that there are two or three other people that are involved at times unfortunately we lose a good staff another person is there as capable as the other guy leaving. A loss of someone probably does not mean that the knowledge is being lost". There was a general notion that the construction industry is project based and that every project is unique therefore adversely affecting the impact of KM. Interviewee J commented that "we are the only industry that is like a mobile factory, other industries have a base, a facility, our business is the only business where the construction site is the factory, and the factory is created to build this thing, when you finish, the factory is taken away and the building is left. The only industry in which we create a factory in each place we build and that's why it's a satelite to all businesses".

Perhaps this effect is felt by personnel and teams who have to split and move on to other various projects. Interviewee A gave a related example; "At the end of this scheme (infrastructure project), there was a review on what has gone well, best practice and what has not gone as well and what you're then hoping for…and this is where I think we fall down a little bit, when you come to the next scheme, or the scheme in 5 years time, unfortunately the people who have gone through that painful experience on the earlier job either are not around with the company or are not the people allocated with the experience of that to the new scheme" KM was found to have less impact on time constraints, budget constraints and organisational culture.

6.3.4 Discussion of findings on the impact of KM on COPQ

There was consensus in the responses from all the interviewees that KM has positive impact in reducing COPQ however, the extent of the impact could not be determined in terms of cost savings as it is neither measured nor tracked by organisations. According to Interviewee C, "there is no measurement in place. If you can't measure you can't manage". Interviewee G asserted that "the one thing you will find extremely difficult in construction is to find anyone who can put a figure on the cost of poor quality because none of us know how to do it, and I meet up with my counterparts from half a dozen big contractors on a regular basis and its one of the things we talk about and its really difficult we just do not know how to cost it". KM can be complex and difficult to manage within organisations and on projects. Provision of data such as the cost and benefits analysis on the amount invested in KM initiatives and the amount saved by reducing COPQ could have helped in understanding the extent of the impact. From literature review, it was revealed that larger organisations in the construction industry are more likely to formally practice KM than the majority of small and medium sized organisations. This study focused on large organisations most of which actually practiced KM but not entirely in a structured way. There was evidence of harnessing and integrating knowledge utilising KM processes (e.g. knowledge sharing and knowledge codification) and tools (e.g. knowledge bases and virtual collaborative workspaces). Other new insights from the findings include the need to develop toolkits to track the impact of KM on COPQ on projects and the need to adopt procurement strategies that support KM at personal, organisational, project and industry levels.

6.4 OPTIMISATION OF KNOWLEDGE MANAGEMENT TO REDUCE THE COST OF POOR QUALITY

The findings from this section are based on the interview questions relating to the barriers to the optimisation of KM to reduce CoPQ which has been discussed in section 5.4.1 (i.e. the design of the semi-structured interviews).

The analysis of the interview data has also been discussed in section 5.4.4. Interviewees were asked the following question: “From your experience in construction projects and organisations, what are the barriers to the optimisation of knowledge management to reduce the cost of poor quality?” Optimisation in the context of this study means making the most effective use of KM to reduce COPQ. It was found that KM currently has not been optimised to reduce COPQ due to a number of barriers which emerged during the interviews.

6.4.1 Key barriers to be addressed to optimise KM

The barriers identified are; lack of assessment, lack of leadership, adversarial organisational culture, time constraints, budget constraints, and procurement strategy.

6.4.1.1 Lack of assessment

It was found that organisations lack tools or frameworks to assess the impact of KM on COPQ. The common theme that emerged from all interviewee responses was that KM has positive impact in reducing certain aspects of COPQ however, none of the interviewees could evaluate the impact. It was found that organisations neither measured nor tracked the impact which is fundamental for optimisation. According to Interviewee C, “If you can’t measure you cant manage, there is a whole new toolkit that needs to come out”. Interviewee E noted that ‘there is no KPI for knowledge management’. It was found that organisations did not have a systematic, structured approach to KM with measurable outputs on COPQ reduction. Interviewee S for example commented that “although we do a lot of knowledge management work, we don’t formally have tools or structured methods”. At industry level, Interviewee A commented that “something that the industry lack is a common data capture format. I think from an industry perspective if we had a common method of collecting data so they could be aggregated and we could share from that, it would help. So a lot have KPIs but they are not universally accepted. If we could collect data in a common fashion then it would be easier for the industry to aggregate their data and learn from it”.

6.4.1.2 Lack of leadership

Apart from lack of performance metrics, there was a lack of leadership i.e. the absence or ineffectiveness of knowledge champions or coordinators to facilitate KM within organisations and on projects. In certain cases where there were knowledge champions, they did not get full support of senior management. According to Interviewee R, “you have to have a knowledge champion, sometimes these people wouldn’t send bits of information in so I had to set up a process of visiting them regularly and phoning them regularly to keep them motivated and part of the job was getting the information in”

6.4.1.3 Adversarial organisational culture

Organisational culture can be adversarial to the optimisation of KM. One of the most significant adversarial culture is ‘knowledge hoarding’ by personnel i.e. unwillingness of individuals to share knowledge. Personnel tend to to crave authority and influence, guarding information therefore is perceived as gaining upper hand or competitive advantage. Some feel that their jobs may be at risk if they share all they know with their organisation and their colleagues therefore the way to maintain job security is to be the only person who knows how to perform a specific function. Blame culture is another significant adversarial culture within organisations and on projects. Blame culture holds individuals or organisations responsible for comitting errors or mistakes rather than incentivising for success. This discourages individuals or organisations from reporting mistakes thereby preventing lessons learnt. There is also a culture of "build it wrong and then fix it afterwards" in the construction industry whereby errors, mistakes or snags are percieved as 'normal', and provisions standardly made in the contracts to rectify them.

6.4.1.4 Time constraints

The barrier of time contraints relate to the perception that KM activities are time consuming therefore adversely affecting project schedule and the productivity of staff. According to Inerviewee G "some of the barriers are time and having the time because we are so task focused they just want to get on and when they finish that project they just want to get on and do the next project they don't take the time to think about what has gone well what didn't go well, what could we improve, they just want to get on to do the next job". Interviewee E commented that "no one has too much time to sit on a round table discussing knowledge sharing et cetera, they've got to get to work".

6.4.1.5 Budget constraints

Budget constraints barrier stems from the evidence that construction has gone back to the adversarial cost driven era rather than the value driven one. The supply chain organisations are too cost constrained to carry out KM activities.

6.4.1.6 Procurement strategy

Procurement strategy can be a key barrier if it does not facilitate integration and collaborative working of supply chain which is crucial to new knowledge creation on processes and products. The right strategy can minimise supply chain organisations striving for competitive advantage and maximisation of profit rather than collaborating for the best outcome of the project. One of such examples was given by Interviewee U thus ‘I think it depends on the type of contract, sometimes the NEC contract or the ECI contract has a lot of early involvement so you spot the problems but if its like ICE7 and so on, you get the drawings and the tenders first, then the bill of quantities”. In other words certain contracts stipulate early involvement of the supply chain while others do not.

6.4.2 Strategy for optimising KM to reduce COPQ

Optimising or making the most effective use of KM to reduce COPQ therefore involves overcoming the barriers identified. These are summarised in 6 steps:

(1) Develop performance metrics to assess the impact of KM on COPQ on projects
(2) Appoint knowledge champions to facilitate KM activities to reduce COPQ
(3) Adopt a positive organisational culture towards KM
(4) Allocate adequate time for KM activities on projects
(5) Allocated adequate budget for KM activities on projects
(6) Select procurement strategies that support and facilitate KM

6.5 IMPLICATIONS OF FINDINGS

The qualitative study provided an insight into the current KM practices within the construction supply chain. It identified the contributory factors to COPQ and the impact of KM in reducing the costs related to those factors. It identified the key steps to optimising KM to reduce COPQ. Findings from the qualitative study has practical relevance and potential application in providing construction organisations with the insight that; investing in KM and quality management techniques, technologies and systems is important but what is more important is the ability to track the impact of the investment in cost terms. The output from the study is envisaged to enable organisations surmount the barriers identified in order to optimise KM to reduce COPQ. However the findings from the study generated further questions. Since the interviewees could not measure the impact of KM on COPQ, this raises a further question: What is the level of impact of KM in reducing COPQ? The barriers to KM were identified from the findings but another question is: How strong are these barriers? In other words, how easy or how difficult is it to overcome the barriers? There are perceived benefits to KM optimisation which were identified, but do these hold true for the rest of the industry?

It is also important to note that the knowledge generated from the qualitative study cannot be generalised as in the case of most qualitative studies in which findings may be unique to the relatively few participants included in the study. As a result, a follow-up quantitative study is conducted with a larger sample of participants in order to address further questions that were generated from the qualitative study. The impact of KM will be assessed in terms of processes and tools. Four key questions are to be addressed in the quantitative study:

(1) What is the level of impact of KM processes on design changes, errors and omissions, and poor skills?

(2) How effective are KM tools in reducing design changes, errors and omissions, and poor skills?

(3) How strong are the barriers to KM optimisation in reducing COPQ?

(4) What are the key benefits of KM optimisation?

6.6 MODIFICATION OF THE CONCEPTUAL FRAMEWORK

The conceptual framework has been modified to incorporate further questions to be addressed through quantitative study (see Figure 6.2). The four further questions identified in Section 6.5 have been incorporated to Element [E] of the framework. A final KM framework for reducing COPQ can then be developed through the findings from the quantitative study and the analysis of the entire research data.

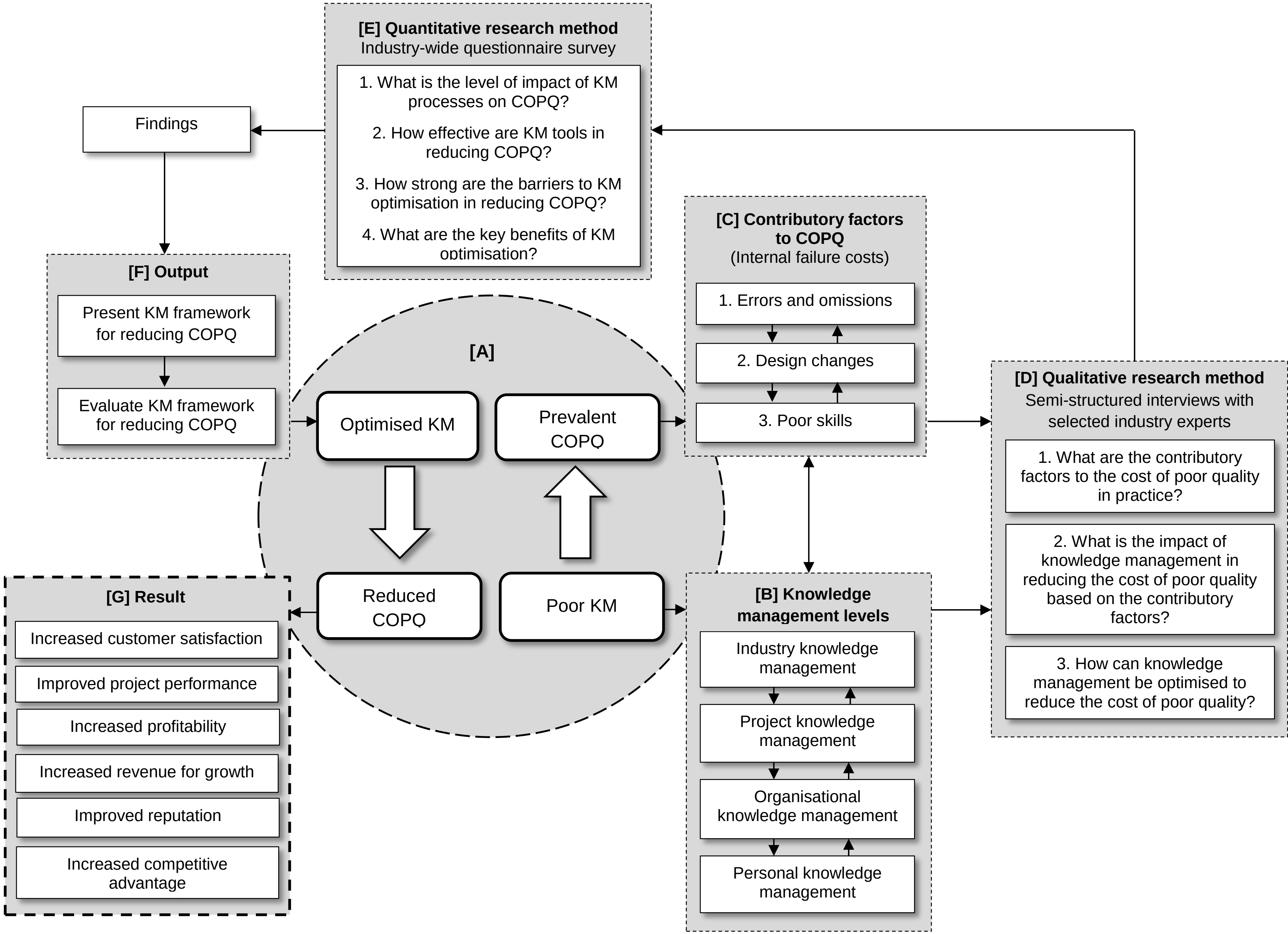


Figure 6. 2: Modified conceptual framework on the impact of KM in reducing COPQ

6.7 SUMMARY OF CHAPTER 6

Chapter 6 discussed the results from the qualitative study on the impact of KM on COPQ. It presented the profile of the interviewees involved in the study. It discussed the findings on the contributory factors to the COPQ in practice which includes the cost of errors and omissions, cost of design changes and the cost of poor skills. The chapter discussed the findings on the impact of KM on these costs. It presented and discussed the findings on the optimisation of KM to reduce the COPQ on construction projects. It was found that KM had positive impact in reducing these costs but it is uncertain by how much. In order to optimise KM, organisations need to: develop performance metrics to measure or track the impact of KM on COPQ; appoint knowledge champions or knowledge coordinators to facilitate KM; cultivate positive organisational culture towards KM e.g. willingness to readily share knowledge and also pull knowledge from existing knowledge resources within the organisation; allocate appropriate time and budget for KM activities; encourage integration and collaborative working among the supply chain. The chapter discussed the implications of the findings and presented four further questions to be addressed through quantitative study. It also presented a modified conceptual framework incorporating these questions, and draws conclusions on the overall qualitative study.

CHAPTER 7

QUANTITATIVE STUDY ON THE IMPACT OF KNOWLEDGE MANAGEMENT ON THE COST OF POOR QUALITY

This chapter presents the results of the quantitative data obtained through questionnaire survey. It discusses the findings on the impact of KM processes for reducing COPQ on construction projects, the effectiveness of KM tools in reducing COPQ, the barriers to KM in reducing COPQ, the benefits of reducing COPQ through KM optimisation. The chapter also discusses the implications of the findings and conclusions.

7.1 RESPONDENT PROFILE

The survey questionnaire design, content and administration have been discussed in Section 5.5.1. The questionnaire template is found in Appendix 5. The profile of the respondents to the survey questionnaire is presented in this section. It includes the respondents' years of work experience, their job designation, current job level, project experience, and their level of familiarity with knowledge management and quality management. Table 7.1 shows the years of experience of the respondents which range from less than 5 years to over 25 years. This represents a wide range of experiences within the construction industry which adds to the richness of the data collected. While 4.4% have less than 5 years of experience, 12.3% have over 25 years of experience. Majority of the respondents work experience fall between 11 years and 20 years (55.2% of total).

Table 7. 1: Years of work experience

	Frequency	Percent	Valid Percent	Cumulative %
<5yrs	5	4.4	4.4	4.4
6 - 10yrs	15	13.2	13.2	17.5
11 - 15yrs	33	28.9	28.9	46.5
16 - 20yrs	30	26.3	26.3	72.8
21 - 25yrs	17	14.9	14.9	87.7
>25yrs	14	12.3	12.3	100.0
Total	114	100.0	100.0	

Respondents' jobs cut across 11 designations with project engineering and project management representing 40.4% of total. Project managers and project engineers play a significant role in ensuring that projects are delivered in accordance to original project plans. Civil engineering and architecture represent 17.5% and 8.8% of total while knowledge management and quality management represent 7% each.

Table 7. 2: Job designation

	Frequency	Percent	Valid Percent	Cumulative %
Project Engineering	23	20.2	20.2	20.2
Project Management	23	20.2	20.2	40.4
Civil Engineering	20	17.5	17.5	57.9
Architecture	10	8.8	8.8	66.7
Quantity Surveying	10	8.8	8.8	75.4
Knowledge Management	8	7.0	7.0	82.5
Quality Management	8	7.0	7.0	89.5
Cost Management	6	5.3	5.3	94.7
Mechanical & Electrical	2	1.8	1.8	96.5
Site Management	2	1.8	1.8	98.2
Site Supervision	2	1.8	1.8	100.0
Total	114	100.0	100.0	

Respondents' job level ranges from director level to operational level enabling a wide spectrum of responses. Operational level amounts to 26.3% of total. Management level can be summed up as 59.6% while director level represents 14%.

Table 7. 3: Current job level

	Frequency	Percent	Valid Percent	Cumulative %
Operational	30	26.3	26.3	26.3
Junior Management	25	21.9	21.9	48.2
Mid-level Management	22	19.3	19.3	67.5
Senior Management	21	18.4	18.4	86.0
Director	16	14.0	14.0	100.0
Total	114	100.0	100.0	

Respondents' project experiences include highways, utility and rail, with building construction having 53.5% of total.

Table 7. 4: Project experience

	Frequency	Percent	Valid Percent	Cumulative %
Building Construction	61	53.5	53.5	53.5
Highways	23	20.2	20.2	73.7
Utility (Power)	19	16.7	16.7	90.4
Rail	6	5.3	5.3	95.6
Utility (Water)	3	2.6	2.6	98.2
Other (Please specify)	2	1.8	1.8	100.0
Total	114	100.0	100.0	

7.2 IMPACT OF KM PROCESSES ON COPQ

Respondents were asked to rate the level of impact of KM processes on the constituent elements of COPQ i.e. design changes, errors and omissions, and poor skills, based on their own experiences on construction projects. A four point Likert scale was utilised to rate the impact as follows: 1 = Strong Negative Impact, 2 = Negative Impact, 3 = Positive Impact, 4 = Strong Positive Impact. The mean values for the ratings were then calculated and ranked in descending order in order to identify the processes that have had most impact and least impact on COPQ in practice. Fifteen KM process-related variables were presented to the respondents to rate their impact on COPQ. The results are presented under three sub-headings (1) Impact of KM processes on design changes (2) Impact of KM processes on errors and omissions (3) Impact of KM processes on poor skills.

7.2.1 Impact of KM processes on design changes

The data from Table 7.5 shows 114 valid responses for each variable. The minimum and maximum ratings for all the variables are 3 and 4 respectively. These signify ‘positive impact’ and ‘strong positive impact’ respectively for the variables. The mean values for the variables shown in the table are ranked in descending order from the highest (3.5175) to the lowest (3.1053). The five highest ranking variables that impact design changes are: knowledge sharing-early involvement; knowledge creation; knowledge capture- project to project; knowledge sharing among project team; and knowledge dissemination.

It is apparent from the table that early involvement of the supply chain has the strongest impact in reducing design changes and associated costs. This is linked to the second highest ranking variable i.e. knowledge creation. Knowledge creation often results from collaborative working among personnel from supply chain organisations particularly in the early stages of a project. New knowledge is usually created around processes and products e.g. new product interfaces and constructability of design. Knowledge capture from project to project has also ranked high among other variables. This implies that design change-related issues have reduced as a result of knowledge capture from other projects. Knowledge sharing among project team members and knowledge dissemination have also ranked high. The five lowest ranking variables that impact design changes are: knowledge champions; knowledge identification; knowledge dissemination- communities of practice; and knowledge transfer- mentoring.

Table 7. 5: Impact of KM processes on design changes

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Knowledge sharing- early involvement	114	1.00	3.00	4.00	3.5175	.50190
Knowledge creation	114	1.00	3.00	4.00	3.5088	.50213
Knowledge capture- project to project	114	1.00	3.00	4.00	3.3772	.48682
Knowledge sharing among project team	114	1.00	3.00	4.00	3.3070	.46329
Knowledge dissemination- publications	114	1.00	3.00	4.00	3.2632	.44229
Knowledge capture- project to organisation	114	1.00	3.00	4.00	3.2456	.43235
Knowledge codification- project to document	114	1.00	3.00	4.00	3.2018	.40308
Knowledge capture- personnel to organisation	114	1.00	3.00	4.00	3.2018	.40308
Knowledge codification- personnel to document	114	1.00	3.00	4.00	3.1754	.38202
Knowledge transfer- apprenticeships	114	1.00	3.00	4.00	3.1754	.38202
Knowledge champions	114	1.00	3.00	4.00	3.1667	.37432
Knowledge identification	114	1.00	3.00	4.00	3.1579	.36625
Knowledge dissemination- communities of practice	114	1.00	3.00	4.00	3.1316	.33952
Knowledge storage	114	1.00	3.00	4.00	3.1316	.33952
Knowledge transfer- mentoring	114	1.00	3.00	4.00	3.1053	.30825

7.2.2 Impact of KM processes on errors and omissions

As shown in Table 7.6, the minimum and maximum ratings for all the variables are 3 and 4 respectively. These signify ‘positive impact’ and ‘strong positive impact’ respectively for the variables. The mean values for the variables shown in the table are ranked in descending order from the highest (3.5) to the lowest (3.1404). The five highest ranking variables that impact errors and omissions are: knowledge capture- project to organisation; knowledge champions; knowledge sharing among project team; knowledge creation: and knowledge transfer- mentoring. Knowledge capture from projects to organisation involves capturing project knowledge and lessons learnt from previous projects and applying the knowledge on current and future projects. According to the results on the table, this has the most impact in reducing errors and omissions. It is interesting to find that the highest ranking variables are related to personalisation approach to knowledge management rather than the use of technologies. The five lowest ranking variables are knowledge identification; knowledge codification- project to document; knowledge codification- personnel to document; knowledge dissemination- communities of practice; and knowledge storage.

Table 7. 6: Impact of KM processes on errors and omissions

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Knowledge capture- project to organisation	114	1.00	3.00	4.00	3.5000	.50221
Knowledge champions	114	1.00	3.00	4.00	3.4649	.50097
Knowledge sharing among project team	114	1.00	3.00	4.00	3.4561	.50027
Knowledge creation	114	1.00	3.00	4.00	3.3333	.47349
Knowledge transfer- mentoring	114	1.00	3.00	4.00	3.3158	.46688
Knowledge capture- project to project	114	1.00	3.00	4.00	3.2632	.44229
Knowledge capture- personnel to organisation	114	1.00	3.00	4.00	3.2632	.44229
Knowledge transfer- apprenticeships	114	1.00	3.00	4.00	3.2632	.44229
Knowledge sharing- early involvement	114	1.00	3.00	4.00	3.2281	.42144
Knowledge dissemination- publications	114	1.00	3.00	4.00	3.2281	.42144
Knowledge identification	114	1.00	3.00	4.00	3.1930	.39638
Knowledge codification- project to document	114	1.00	3.00	4.00	3.1667	.37432
Knowledge codification- personnel to document	114	1.00	3.00	4.00	3.1491	.35778
Knowledge dissemination- communities of practice	114	1.00	3.00	4.00	3.1404	.34888
Knowledge storage	114	1.00	3.00	4.00	3.1404	.34888

7.2.3 Impact of KM processes on poor skills

As shown in Table 7.7, the minimum and maximum ratings for all the variables are 3 and 4 respectively. These signify ‘positive impact’ and ‘strong positive impact’ respectively for the variables. The mean values for the variables shown in the table are ranked in descending order from the highest (3.6053) to the lowest (3.1140). The five highest ranking variables that impact poor skills are:

knowledge transfer- mentoring; knowledge transfer- apprenticeships; knowledge identification; knowledge capture- personnel to organisation; and knowledge champions. The five lowest ranking variables are knowledge storage; knowledge creation; knowledge dissemination- publications; knowledge codification- project to document; and knowledge capture- project to project.

Table 7. 7: Impact of KM processes on poor skills

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Knowledge transfer- mentoring	114	1.00	3.00	4.00	3.6053	.49095
Knowledge transfer- apprenticeships	114	1.00	3.00	4.00	3.6053	.49095
Knowledge identification	114	1.00	3.00	4.00	3.5351	.50097
Knowledge capture- personnel to organisation	114	1.00	3.00	4.00	3.5263	.50151
Knowledge champions	114	1.00	3.00	4.00	3.2982	.45951
Knowledge codification- personnel to document	114	1.00	3.00	4.00	3.2544	.43744
Knowledge capture- project to organisation	114	1.00	3.00	4.00	3.2368	.42702
Knowledge sharing among project team	114	1.00	3.00	4.00	3.2105	.40948
Knowledge sharing- early involvement	114	1.00	3.00	4.00	3.1842	.38937
Knowledge dissemination- communities of practice	114	1.00	3.00	4.00	3.1491	.35778
Knowledge storage	114	1.00	3.00	4.00	3.1491	.35778
Knowledge creation	114	1.00	3.00	4.00	3.1228	.32966
Knowledge dissemination- publications	114	1.00	3.00	4.00	3.1228	.32966
Knowledge codification- project to document	114	1.00	3.00	4.00	3.1140	.31926
Knowledge capture- project to project	114	1.00	3.00	4.00	3.1140	.31926

Table 7.8 shows a summary of the five highest ranking KM processes impacting design changes, errors and omissions and poor skills elements of COPQ. The commonality among the three elements is knowledge capture i.e. project to project knowledge capture in the case of design changes; project to organisation knowledge capture in the case of errors and omissions; and personnel to organisation knowledge capture in the case of poor skills.

Table 7. 8: Five highest ranking KM processes impacting COPQ

Design changes	Mean	Errors and omissions	Mean	Poor skills	Mean
Knowledge sharing- early involvement	3.5175	Knowledge capture- project to organisation	3.5000	Knowledge transfer- mentoring	3.6053
Knowledge creation	3.5088	Knowledge champions	3.4649	Knowledge transfer- apprenticeships	3.6053
Knowledge capture- project to project	3.3772	Knowledge sharing among project team	3.4561	Knowledge identification	3.5351
Knowledge sharing among project team	3.3070	Knowledge creation	3.3333	Knowledge capture- personnel to organisation	3.5263
Knowledge dissemination- publications	3.2632	Knowledge transfer- mentoring	3.3158	Knowledge champions	3.2982

The five lowest ranking KM processes impacting COPQ are shown in Table 7.9. Knowledge dissemination was found to be common with the three elements of COPQ i.e. communities of practice in the case of design changes and errors; publications in the case of poor skills. Knowledge storage was also found as a commonality of the three elements.

Table 7. 9: Five lowest ranking KM processes impacting COPQ

Design changes	Mean	Errors and omissions	Mean	Poor skills	Mean
Knowledge champions	3.1667	Knowledge identification	3.1930	Knowledge storage	3.1491
Knowledge identification	3.1579	Knowledge codification- project to document	3.1667	Knowledge creation	3.1228
Knowledge dissemination- communities of practice	3.1316	Knowledge codification- personnel to document	3.1491	Knowledge dissemination- publications	3.1228
Knowledge storage	3.1316	Knowledge dissemination- communities of practice	3.1404	Knowledge codification- project to document	3.1140
Knowledge transfer- mentoring	3.1053	Knowledge storage	3.1404	Knowledge capture- project to project	3.1140

7.3 EFFECTIVENESS OF KM TOOLS IN REDUCING COPQ

Respondents were asked to rate the level of effectiveness of KM tools on the constituent elements of COPQ i.e. design changes, errors and omissions, and poor skills, based on their own experiences on construction projects. A four point Likert scale was utilised to rate the effectiveness as follows: 1 = Not at all effective, 2 = Fairly effective, 3 = Effective, 4 = Very effective. The mean values for the ratings were calculated and ranked in descending order so as to identify the processes that have been most effective and least effective in reducing COPQ in practice. A total of twenty four variables relating to KM tools were presented to the respondents to rate their effectiveness in reducing COPQ. The results are presented under three sub-headings (1) Effectiveness of KM tools in reducing design changes (2) Effectiveness of KM tools in reducing errors and omissions (3) Effectiveness of KM tools in reducing poor skills.

7.3.1 Effectiveness of KM tools in reducing design changes

The results presented in Table 7.10 show 114 valid responses for each variable. The mean values for the variables shown in the table are ranked in descending order from the highest (3.3421) to the lowest (2.1053). The five highest ranking variables are: learning reviews; post project reviews; lessons learnt management systems, knowledge sharing workshops; and collaborative physical workspaces. This is an interesting set of results as they are all interlinked. They all relate to project team capturing, sharing and retaining valuable lessons learnt from on-going or concluded projects. Not surprisingly, these tools have shown high level of effectiveness in reducing design changes and associated costs on projects according to the results. The five lowest ranking variables however are: instant messenger; peer assist; blogs; intranets; competency management. Their ratings range from ‘not at all effective’ to ‘effective’ with the mean ratings at the ‘fairly effective’ threshold. It is apparent from the results that these tools are less effective in reducing design changes and associated costs.

Table 7. 10: Effectiveness of KM tools in reducing design changes

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Learning reviews	114	2.00	2.00	4.00	3.3421	.52930
Post project reviews	114	2.00	2.00	4.00	3.3333	.55918
Lessons learnt management systems	114	2.00	2.00	4.00	3.3070	.53426
Knowledge sharing workshops	114	2.00	2.00	4.00	3.2895	.60563
Collaborative physical work spaces	114	2.00	2.00	4.00	3.1404	.54654
Learning histories	114	2.00	2.00	4.00	3.1228	.53448
Collaborative virtual work spaces	114	2.00	2.00	4.00	2.9737	.61631
Email	114	2.00	2.00	4.00	2.9386	.56888
Knowledge cafes	114	2.00	2.00	4.00	2.8509	.73150
Cross project learning	114	3.00	1.00	4.00	2.8421	.54169
Knowledge mapping	114	2.00	2.00	4.00	2.8421	.49024
Web conferencing	114	2.00	2.00	4.00	2.7368	.49872
Social networking	114	2.00	2.00	4.00	2.7018	.53098
Knowledge bases	114	3.00	1.00	4.00	2.6579	.91040
Brainstorming	114	3.00	1.00	4.00	2.6491	.57963
Wikis	114	2.00	2.00	4.00	2.6316	.53651
Knowledge exchange- interviews	114	2.00	2.00	4.00	2.6228	.57052
Storytelling	114	3.00	1.00	4.00	2.5614	.53274
Corporate yellow pages	114	3.00	1.00	4.00	2.5351	.53513
Competency management	114	3.00	1.00	4.00	2.4737	.69398
Intranets	114	3.00	1.00	4.00	2.4211	.59340
Blogs	114	3.00	1.00	4.00	2.3860	.77011
Peer assist	114	2.00	1.00	3.00	2.3246	.65845
Instant messenger	114	2.00	1.00	3.00	2.1053	.62921

7.3.2 Effectiveness of KM tools in reducing errors and omissions

The mean values for the variables shown in Table 7.11 the table are ranked in descending order from the highest (3.3421) to the lowest (2.2807). The five highest ranking variables are: learning reviews; lessons learnt management systems; knowledge sharing workshops; post project reviews; and collaborative physical workspaces. The results on this table are comparable to those on Table 7.10 which ranks knowledge sharing, reviews and collaboration high in effectiveness. The five lowest ranking variables however are: peer assist; blogs; intranets; cooperate yellow pages; and instant messenger. It is apparent from the results that these tools less effective in reducing errors and omissions. It is understandable that tools like blogs and instant messenger did not add much value to reducing errors on site, however it is surprising that peer assist falls within the bottom five.

Table 7. 11: Effectiveness of KM tools in reducing errors and omissions

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Learning reviews	114	2.00	2.00	4.00	3.3421	.56174
Lessons learnt management systems	114	1.00	3.00	4.00	3.3070	.46329
Knowledge sharing workshops	114	2.00	2.00	4.00	3.2895	.56008
Post project reviews	114	2.00	2.00	4.00	3.1842	.54148
Collaborative physical work spaces	114	2.00	2.00	4.00	3.1228	.50027
Cross project learning	114	2.00	2.00	4.00	3.1140	.45620
Knowledge bases	114	2.00	2.00	4.00	3.0789	.73043
Learning histories	114	2.00	2.00	4.00	3.0263	.43028
Web conferencing	114	2.00	2.00	4.00	2.8772	.48226
Knowledge cafes	114	2.00	2.00	4.00	2.8684	.61706
Knowledge mapping	114	2.00	2.00	4.00	2.8333	.54718
Collaborative virtual work spaces	114	3.00	1.00	4.00	2.8070	.66355
Wikis	114	2.00	2.00	4.00	2.7807	.60615
Brainstorming	114	3.00	1.00	4.00	2.7807	.57621
Email	114	2.00	2.00	4.00	2.7544	.57317
Competency management	114	3.00	1.00	4.00	2.7281	.56888
Knowledge exchange- interviews	114	2.00	2.00	4.00	2.7193	.52392
Social networking	114	2.00	2.00	4.00	2.6316	.50244
Storytelling	114	2.00	1.00	3.00	2.6053	.50866
Peer assist	114	2.00	1.00	3.00	2.5263	.58310
Blogs	114	3.00	1.00	4.00	2.4474	.61099
Intranets	114	3.00	1.00	4.00	2.3684	.51975
Corporate yellow pages	114	2.00	1.00	3.00	2.3509	.60940
Instant messenger	114	3.00	1.00	4.00	2.2807	.67192

7.3.3 Effectiveness of KM tools in reducing poor skills

The results presented in Table 7.12 shows the mean values for each of the twenty four (24) KM tool-related variables which are ranked in descending order from the highest (3.4737) to the lowest (2.1579). The five highest ranking variables are: post project reviews; competency management; peer assist; lessons learnt management systems; and knowledge sharing workshops.

Table 7. 12: Effectiveness of KM tools in reducing poor skills

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Post project reviews	114	2.00	2.00	4.00	3.4737	.55192
Competency management	114	2.00	2.00	4.00	3.2368	.58450
Peer assist	114	2.00	2.00	4.00	3.2018	.56724
Lessons learnt management systems	114	2.00	2.00	4.00	3.1754	.53622
Knowledge sharing workshops	114	2.00	2.00	4.00	3.1667	.57863
Cross project learning	114	2.00	2.00	4.00	3.1316	.55675
Knowledge exchange- interviews	114	2.00	2.00	4.00	3.1228	.46354
Storytelling	114	2.00	2.00	4.00	3.0614	.56888
Knowledge cafes	114	2.00	2.00	4.00	3.0088	.58741
Learning reviews	114	2.00	2.00	4.00	3.0000	.57990
Corporate yellow pages	114	3.00	1.00	4.00	2.9912	.54033
Collaborative physical work spaces	114	2.00	2.00	4.00	2.8860	.56064
Web conferencing	114	2.00	2.00	4.00	2.8596	.47740
Knowledge mapping	114	2.00	2.00	4.00	2.8509	.53600
Learning histories	114	2.00	2.00	4.00	2.7719	.51586
Social networking	114	2.00	2.00	4.00	2.7632	.50313
Knowledge bases	114	2.00	2.00	4.00	2.7456	.51200
Collaborative virtual work spaces	114	3.00	1.00	4.00	2.6930	.63979
Blogs	114	3.00	1.00	4.00	2.5351	.59763
Brainstorming	114	3.00	1.00	4.00	2.4035	.60557
Wikis	114	2.00	1.00	3.00	2.3947	.52577
Instant messenger	114	2.00	1.00	3.00	2.2719	.62803
Intranets	114	2.00	1.00	3.00	2.2105	.48834
Email	114	3.00	1.00	4.00	2.1579	.60351

The results on this table are also comparable to those on Table 7.10 and Table 7.11 which ranks knowledge sharing, reviews and collaboration high in effectiveness. An addition to the top ranking tools however is peer assist. This is not surprising though as peer assist brings together group of peers to elicit feedback on a problem, project, or activity, and draw lessons from the participants' knowledge and experience. The five lowest ranking variables however are: brainstorming; wikis; instant messenger; intranets; and email. This is understandable as it may be difficult to envisage the use of emails and instant messenger effectively to reduce poor skills.

Examining Tables 7.10, 7.11, and 7.12, there is a clear trend, pattern and consistency to the five highest ranking tools. Firstly they all relate to collaboration in sharing knowledge and learning from past mistakes to reduce COPQ. Secondly, they are all personalisation tools (techniques) except for lessons learnt management systems which is a codification tool (technologies). Thirdly, there are three commonalities of variables to the elements of COPQ. They are: post project reviews; lessons learnt management systems; and knowledge sharing workshops. It is evident that these three variables seem important and are very effective in reducing design changes, errors and omissions and poor skills. Collaborative physical work places and learning reviews cut across design changes and errors and omissions while competency management and peer assist are more effective in reducing poor skills and associate costs (Table 7:13).

Table 7. 13: Five highest ranking KM tools for reducing COPQ

Design changes	Mean	Errors and omissions	Mean	Poor skills	Mean
Learning reviews	3.3421	Learning reviews	3.3421	Post project reviews	3.4737
Post project reviews	3.3333	Lessons learnt management systems	3.3070	Competency management	3.2368
Lessons learnt management systems	3.3070	Knowledge sharing workshops	3.2895	Peer assist	3.2018
Knowledge sharing workshops	3.2895	Post project reviews	3.1842	Lessons learnt management systems	3.1754
Collaborative physical work spaces	3.1404	Collaborative physical work spaces	3.1228	Knowledge sharing workshops	3.1667

Table 7.14 shows the summary of the five lowest ranking KM tools for reducing COPQ. The common tools that cut across design changes, errors and omissions and poor skills are; intranets and instant messenger. Apart from peer assist, competency management and brainstorming, it is interesting to find that most of the lowest ranking tools are codification tools which involve the use of technologies and technological infrastructure. Instant messenger has ranked lowest in two categories and is also included in the third category which makes it almost the least effective tool in reducing COPQ.

Table 7. 14: Five lowest ranking KM tools for reducing COPQ

Design changes	Mean	Errors and omissions	Mean	Poor skills	Mean
Competency management	2.4737	Peer assist	2.5263	Brainstorming	2.4035
Intranets	2.4211	Blogs	2.4474	Wikis	2.3947
Blogs	2.3860	Intranets	2.3684	Instant messenger	2.2719
Peer assist	2.3246	Corporate yellow pages	2.3509	Intranets	2.2105
Instant messenger	2.1053	Instant messenger	2.2807	Email	2.1579

7.4 BARRIERS TO KM IN REDUCING COPQ

Respondents were presented with 16 variables relating to KM barriers to reducing COPQ and were asked to rate the level of strength of the barriers based on their own experiences on construction projects. A four-point Likert was utilised to rate the barriers as follows: 1 = Very Weak Barrier, 2 = Weak Barrier, 3 = Strong Barrier, 4 = Very Strong Barrier. The rationale behind this is to identify the most critical barriers that need to be addressed in order to optimise KM to reduce COPQ. The mean values for the ratings of each variable were calculated and ranked in descending order so as to identify the barriers that are most critical to address. The results presented in Table 7.15 show 114 valid responses for each variable. The mean values for the variables shown in the table are ranked in descending order from the highest (3.5965) to the lowest (2.6842). The five highest ranking variables are: lack of performance metrics; adversarial organisational culture; lack of collaborative working; perception of errors as inevitable; and adversarial procurement strategy.

Table 7. 15: Barriers to KM in reducing COPQ

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Lack of performance metrics	114	1.00	3.00	4.00	3.5965	.49277
Adversarial organisational culture	114	2.00	2.00	4.00	3.4737	.64094
Lack of collaborative working	114	1.00	3.00	4.00	3.3860	.48897
Perception of errors as inevitable	114	1.00	3.00	4.00	3.3860	.48897
Adversarial procurement strategy	114	1.00	3.00	4.00	3.3596	.48202
Time constrained nature of projects	114	2.00	2.00	4.00	3.3158	.62847
High staff turnover	114	2.00	2.00	4.00	3.2456	.45236
Lack of knowledge champions	114	2.00	2.00	4.00	3.2018	.50097
Lack of senior management support	114	2.00	2.00	4.00	3.1404	.66355
KM activities are unnecessary burden	114	2.00	2.00	4.00	3.0439	.61530
High cost of investing in KM	114	2.00	2.00	4.00	2.9912	.55647
Complacency of personnel	114	2.00	2.00	4.00	2.9737	.57161
Lack of incentives to motivate personnel	114	2.00	2.00	4.00	2.9035	.54803
Knowledge hoarding	114	2.00	2.00	4.00	2.8684	.73488
Lack of understanding of KM concepts	114	2.00	2.00	4.00	2.8596	.59313
Lack of KM technological infrastructure	114	3.00	1.00	4.00	2.6842	.50337

The five lowest ranking variables are: complacency of personnel; lack of incentives to motivate personnel; knowledge hoarding; lack of understanding of KM concepts; and lack of technological infrastructure.

7.5 BENEFITS OF REDUCING COPQ THROUGH KM OPTIMISATION

Respondents were presented with a list of 11 variables relating to the benefits of reducing COPQ through the optimisation of KM. They were asked to rate the benefits based on their experiences on construction projects utilising a four-point Likert scale as follows: 1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree. The rationale behind this is to identify the top benefits organisations gain from reducing COPQ and how they fit into their organisational strategy. The mean values for the ratings of each variable were calculated and ranked in descending order so as to identify the top benefits of reducing COPQ through KM. The results presented in Table 7.16 show 114 valid responses for each variable. The mean values for the variables shown in the table are ranked in descending order from the highest (3.1842) to the lowest (3.0614). The three highest ranking variables are: increased revenue for growth; improved process quality; and improved project performance. The three lowest ranking variables are: increased staff motivation; improved reputation of organisation; and increased profitability.

Table 7. 16: Benefits of reducing COPQ through KM optimisation

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Increased revenue for growth	114	1.00	3.00	4.00	3.1842	.38937
Improved process quality	114	1.00	3.00	4.00	3.1667	.37432
Improved project performance	114	1.00	3.00	4.00	3.1404	.34888
Increased customer satisfaction	114	2.00	2.00	4.00	3.1316	.41033
Improved product quality	114	1.00	3.00	4.00	3.1316	.33952
Increased competitive advantage	114	1.00	3.00	4.00	3.1316	.33952
Improved cost efficiency	114	1.00	3.00	4.00	3.1228	.32966
Improved service quality	114	2.00	2.00	4.00	3.1140	.37057
Increased staff motivation	114	2.00	2.00	4.00	3.1140	.34587
Improved reputation of organisation	114	2.00	2.00	4.00	3.1140	.34587
Increased profitability	114	2.00	2.00	4.00	3.0614	.40539

7.6 MEASUREMENT OF THE IMPACT OF KM ON COPQ

Respondents were asked ten questions relating to the measurement of the impact of KM on COPQ based on the findings from qualitative data analysis. The questions relate to respondents' experiences in their organisation and on projects they have been involved in. Respondents were given two options to either answer 'yes' or 'no' to the questions asked. All responses received were unanimous and are summarised below.

Do you currently have a tool to quantify COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
No	114	100.0	100.0	100.0

Do you currently have a tool that measures the impact of KM on COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
No	114	100.0	100.0	100.0

Do you currently have performance metrics to assess the impact of KM on COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
No	114	100.0	100.0	100.0

Would you welcome a new tool for:

Quantifying COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Measuring the impact of KM on COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Developing performance metrics for assessing the impact of KM on COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Comparing the performances of various projects on the impact of KM on COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Measuring the costs and benefits of KM in reducing COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Tracking periodical progress of KM in reducing COPQ?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

Assessing the impact of KM on overall project cost?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	114	100.0	100.0	100.0

7.7 IMPLICATION OF FINDINGS

The implication of the findings is the modification of the conceptual framework. Component [E] of the framework has been updated to include the findings from the industry questionnaire survey which identified the followings: the high impact KM processes in reducing COPQ; high impact KM tools for reducing COPQ; top barriers to KM optimisation; and the key benefits of KM. The modified conceptual framework is presented in Figure 7.1.

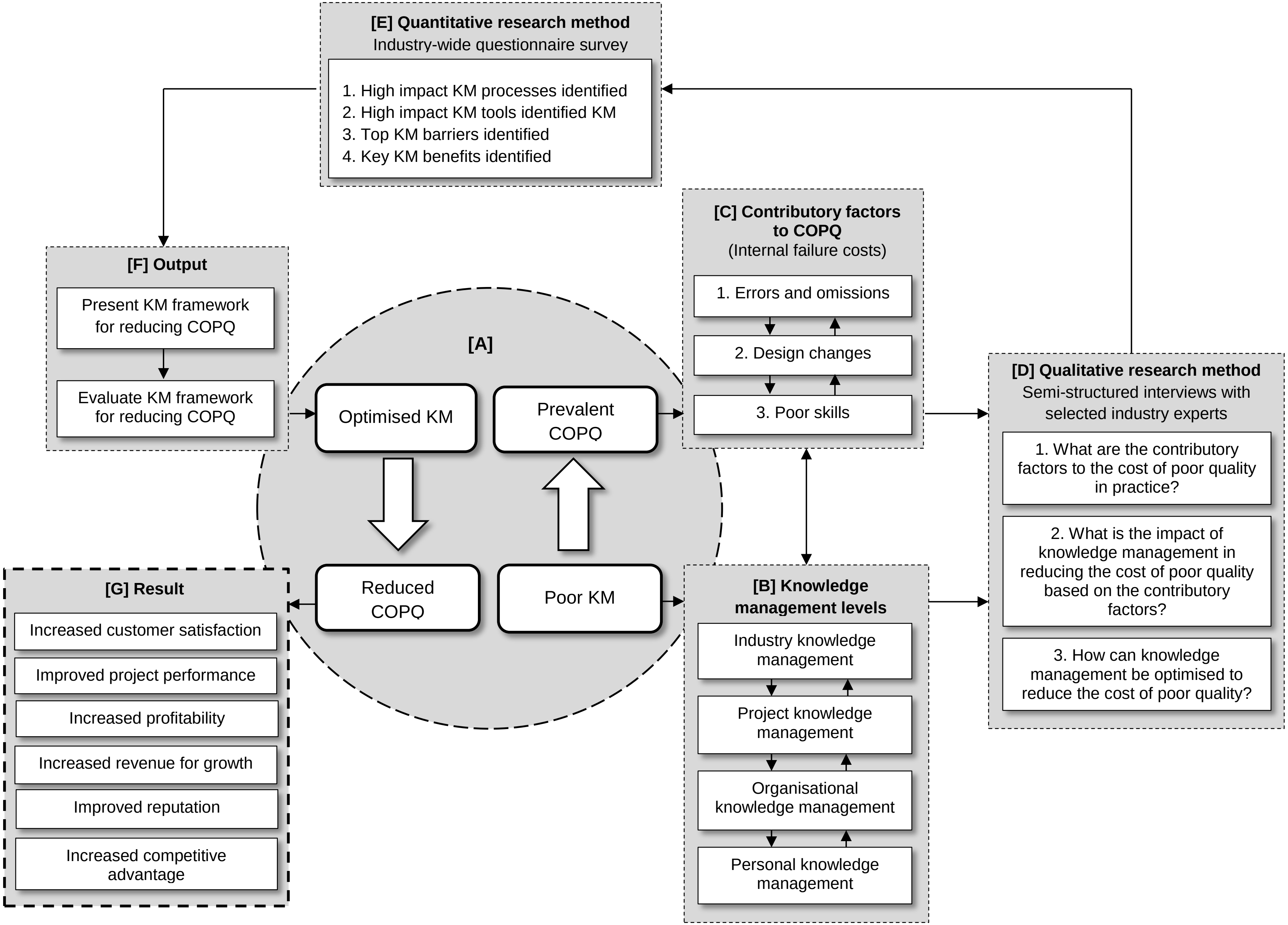


Figure 7. 1: Modified conceptual framework on the impact of KM in reducing COPQ

7.8 SUMMARY OF CHAPTER 7

The chapter presented the results of the quantitative data obtained through questionnaire survey. It discussed the findings on the impact of KM processes for reducing COPQ on construction projects, the effectiveness of KM tools in reducing COPQ, the barriers to KM in reducing COPQ, the benefits of reducing COPQ through KM optimisation, and the measurement of the impact of KM on COPQ. It was found that the KM processes that had the most impact in reducing COPQ are related to the socialisation aspect of the SECI model such as knowledge sharing, new knowledge creation, knowledge transfer through mentoring and apprenticeships. Similarly the most effective KM tools for reducing COPQ were related to socialisation such as learning reviews, post project reviews, knowledge sharing workshops and collaborative physical workspaces. The top barriers to KM in reducing COPQ were identified as lack of performance metrics, adversarial organisational culture, lack of collaborate working, perception of errors as inevitable, and adversarial procurement strategy. The top benefits were identified as increased revenue for growth, improved process quality, improved project performance and increased customer satisfaction.

CHAPTER 8

KNOWLEDGE MANAGEMENT FRAMEWORK FOR REDUCING THE COST OF POOR QUALITY IN CONSTRUCTION PROJECTS

This chapter presents an interpretation of the entire data i.e. qualitative and quantitative. It connects all aspects of the research including the main research questions, findings and conclusions from both qualitative and quantitative inquiries. It discusses the overall impact of knowledge management on errors and omissions, design changes and poor skills. It presents the knowledge management framework for reducing the cost of poor quality on construction projects. It also discusses the evaluation of the framework.

8.1 INTERPRETATION OF THE ENTIRE DATA

Exploratory sequential mixed methods research design was adopted due to the nature of the research problem and the research questions being addressed on the impact of KM in reducing COPQ on construction projects. This commenced with a qualitative research phase which explored the views of participants and addressed the key research questions. The data collected from this phase were then analysed, and the findings used to build into a second, quantitative phase. The qualitative phase was used to build an instrument that best fits the sample under study, to identify appropriate instruments to use in the follow-up quantitative phase and to specify variables for the follow-up quantitative study. Qualitative data was collected using semi-structured interviews while quantitative data was collected using survey questionnaires. It was therefore important to synthesise and interpret the entire data in order to reach logical conclusions for the research. This requires examining the link between the main research questions, the findings from the qualitative study, further questions generated and findings from the quantitative study.

Table 8.1 summarises the exploratory sequential mixed methods research findings and conclusions. Three main research questions were addressed through qualitative inquiry while further questions and hypotheses were addressed by quantitative inquiry. The first research question was aimed at investigating the contributory factors to COPQ in practice. Although the causes or the key elements to COPQ have been identified from literature review as design changes, errors and omissions, and poor skills, this may not be entirely accurate in the local context of the UK construction industry moreover these causes identified from literature were closely linked with the manufacturing industry. It was therefore important to investigate the main causes of COPQ and their contributory factors through exploratory study conducted with construction industry experts. It was found from the analysis of the qualitative data that the main causes of COPQ identified from literature can be localised in the UK construction industry.

Other causes were also identified such as product damages resulting from transportation, vandalism on site and other unforeseen risks however the findings were site-specific and could not be generalised for the industry moreover these causes were not entirely related to KM issues. The rationale behind investigating the contributory factors to COPQ is to identify the commonality of the factors that cut across all project types based on participants' experiences. A total of 12 factors were found in common that contributed to the cost of errors and omissions regardless of project types.

Table 8. 1: Exploratory sequential mixed methods research findings and conclusions

Main research questions	**Findings from qualitative inquiry**	**Conclusions from qualitative inquiry**	**Further research questions to be addressed**	**Findings from quantitative inquiry**	**Conclusions from quantitative inquiry**
1. What are the contributory factors to the cost of poor quality in practice?	• Contributory factors in practice can be classified into errors and omissions, design changes and poor skills as identified in theory • 12 factors contributed to the cost of errors and omissions • 11 factors to the cost of design changes • 8 to the cost of poor skills • 5 recurrent or common factors were identified: procurement strategy, poor communication, organisational culture, time constraints and budget constraints. • There are other factors but are project specific and cannot be generalised	• Errors and omissions, design changes and poor skills are not mutually exclusive but are interrelated, overlapping or causal in nature. • Organisations do not quantify COPQ on construction projects	• Can the findings and conclusions be generalised?	• There was unanimous response that organisations do not quantify COPQ	COPQ cannot be managed if it cannot be properly quantified
2. What is the impact of knowledge management in reducing the cost of poor quality on construction projects?	• There was evidence of KM initiatives, practices and activities at personal, organisation and project levels however there was little evidence of industry level KM practices • There was evidence of the use of KM processes and tools • Overall, the impact of KM in reducing COPQ is perceived as positive • However none of the participant organisations could measure or assess the impact of KM on COPQ • There was evidence of perceived benefits realised from the positive impact of KM in reducing COPQ	• KM has positive impact in reducing COPQ on construction projects • Organisations do not measure the impact of KM on COPQ on projects • Organisations do not have performance metrics to assess the impact of KM on COPQ on projects	• What is the level of impact of KM processes on COPQ? • How effective are KM tools in reducing COPQ? • Can the lack of measurement of the impact of KM be generalised for the industry?	• KM has positive impact in reducing COPQ on construction projects • The level of impact of KM processes on COPQ range from positive impact to strong positive impact. • Personnel-related KM processes were found to have more impact in reducing COPQ than technology –related processes • KM techniques were found to be more effective in reducing COPQ than KM technologies There was unanimous response that organisations do not: • Measure the impact of KM on COPQ • Have performance metrics to assess the impact of KM on COPQ	• KM has positive impact but has not been fully optimised in reducing COPQ Contrary to the perception that KM initiatives are capital intensive and require technological infrastructure; • Personnel-related KM processes have more impact in reducing COPQ than technology –related processes • KM techniques are more effective in reducing COPQ than KM technologies • In-ability to measure the impact of KM on COPQ makes bench marking and continuous improvement in the reduction of COPQ on projects difficult.

		• KM has perceived benefits in reducing COPQ on projects	• Which are the top benefits of KM in reducing COPQ?	• Top benefits are: increased revenue for growth, improved process quality, improved project performance, improved customer satisfaction	
3. How can knowledge management be optimised to reduce the cost of poor quality?	KM can be optimised to reduce COPQ by addressing the key barriers: • Lack of performance metrics to assess the impact of KM on COPQ on projects • Lack of knowledge champions to facilitate KM activities to reduce COPQ • Adversarial organisational culture towards KM • In-adequate time for KM activities • In-adequate budget for KM activities • Procurement strategy	• KM has currently not been optimised to reduce COPQ due to key barriers • KM has further potential in reducing COPQ	• Can the findings be generalised? • What is the level of strength of the barriers? • Which are the top barriers?	The top KM barriers in the wider construction industry are: • Lack of performance metrics • Adversarial organisational culture • Lack of collaborative working • Perception of errors as inevitable • Adversarial procurement strategy	• The key barriers identified from qualitative inquiry can be generalised in the industry. KM can therefore be optimised to reduce COPQ by addressing the key barriers • There is a link between the contributory factors to COPQ and the barriers to KM. They are: procurement strategy, organisational culture, time and budget constraints

They include rule-based mistakes, knowledge-based mistakes, slips and lapses and attention. 11 factors were found to contribute to the cost of design changes which include changes initiated by clients, organisations in the supply chain or external stakeholders. 8 factors were found to contribute to poor skills which include high personnel turnover, lack of training and lack of dedication. A total of 5 recurrent or common factors were identified which cut across at least two of the causes of COPQ. They are procurement strategy, poor communication, organisational culture, time constraints and budget constraints therefore making these factors critical to address.

The second research question was aimed at investigating the impact of KM in reducing COPQ on construction projects. There was evidence of KM initiatives, practices and activities at personal, organisational and project levels however there was little evidence of industry level initiatives and practices. There was evidence of the utilisation of KM processes e.g. knowledge capture and knowledge sharing. There was also evidence of the utilisation of KM-supporting tools (techniques and technologies) such as learning reviews, post-project reviews, lessons learnt management systems and collaborative physical working spaces. Overall, the impact of KM in reducing COPQ was concluded as positive however none of the participant experts in the qualitative study could substantiate this with calculated data. None of the participant organisations could measure or assess the impact of KM on COPQ although there was evidence of perceived benefits realised from the positive impact.

The third research question relates to the optimisation of KM in reducing COPQ. It was found that KM is not currently being optimised or utilised to its maximum potential due to certain barriers which were identified as: lack of performance metrics to assess the impact of KM on COPQ on projects; lack of knowledge champions to facilitate KM activities to reduce COPQ; adversarial organisational culture towards KM; in-adequate time for KM activities; in-adequate budget for KM activities; and procurement strategy. Conclusions were drawn from the qualitative inquiry as follows: errors and omissions, design changes and poor skills are not mutually exclusive but are interrelated, overlapping and causal in nature; organisations do not quantify COPQ on construction projects; KM has positive impact in reducing COPQ on construction projects; organisations do not measure the impact of KM on COPQ on projects; organisations do not have performance metrics to assess the impact the impact of KM on COPQ on projects; KM has perceived benefits in reducing COPQ on projects; KM has currently not been optimised to reduce COPQ due to the key barriers; KM has further potential in reducing COPQ on projects.

Despite the conclusions reached at the end of the qualitative inquiry, further questions emerged which needed to be addressed through quantitative inquiry e.g. can the findings and conclusions from the qualitative study be generalised for the UK construction industry? What is the level of impact of KM processes on COPQ? How effective are KM tools in reducing COPQ? Can the lack of measurement of the impact of KM be generalised for the industry? Which are the top benefits of KM in reducing COPQ? What is the level of strength of the barriers to KM in reducing COPQ? Can the top barriers of KM be generalised in the industry?

The findings from the quantitative inquiry confirm that organisations do not quantify COPQ on projects and that KM has positive impact in reducing COPQ on construction projects. It was found that the level of impact of KM processes on COPQ range from positive impact to strong positive impact. Personnel-related KM processes were found to have more impact in reducing COPQ than technology-related processes. KM techniques were also found to be more effective in reducing COPQ than KM technologies. It could be generalised that organisations do not measure the impact of KM on COPQ neither do they have performance metrics to assess the impact of KM on COPQ.

The top benefits of KM in reducing COPQ were identified as; increased revenue for growth, improved process quality, improved project performance, improved customer satisfaction. The top KM barriers identified was confirmatory of the ones identified through qualitative inquiry which include lack of performance metrics, adversarial organisational culture, lack of collaborative working, perception of errors as inevitable, and adversarial procurement strategy. The conclusions drawn from the quantitative inquiry was that COPQ cannot be managed if it cannot be properly quantified. The in-ability to measure the impact of KM on COPQ makes bench marking and continuous improvement in the reduction of COPQ on projects difficult. The key barriers identified from qualitative inquiry can be generalised in the industry. KM can therefore be optimised to reduce COPQ by addressing the key barriers. Interestingly there is a link between the contributory factors to COPQ and the barriers to KM. They are; procurement strategy, organisational culture, time and budget constraints.

Having concluded that KM has positive impact in reducing COPQ, the impact can be further classified into high impact and low impact based on research findings. The classification is based on the impact of KM processes and the effectiveness of KM tools. The synthesis of the outputs from both qualitative and quantitative inquiries are interpreted and presented under three sub-headings; Impact of KM on errors and omissions; impact of KM on design changes; and impact of KM on poor skills.

8.1.1 Impact of KM on errors and omissions

The top five KM processes that impact the reduction of errors and omissions, design changes and poor skills were identified from data analysis and redistributed on the KM – COPQ model (Figure 8.1). Socialisation at organisational level KM had the most impact on the reduction of errors and omissions. The facilitation of KM across organisations in the supply chain using knowledge champions; knowledge sharing among project team members; and the creation of new knowledge have particularly ranked high in this area. There was also evidence of socialisation at personal level in form of knowledge transfer from senior personnel of an organisation to junior ones through mentoring. Combination at project level entailed knowledge capture of project knowledge by organisations in the supply chain. However the KM processes having low impact in reducing errors and omissions were found to be knowledge identification, knowledge codification through the conversion of personnel knowledge into organisational knowledge, and knowledge dissemination through communities of practice (Figure 8.2). At project level, knowledge codification from project to document and knowledge storage have low impact.

In terms of the effectiveness of KM tools, socialisation at organisational level was found to be highly effective for reducing errors and omissions (Figure 8.3). This includes learning reviews, knowledge sharing workshops, post project reviews and collaborative physical workspaces. Lessons learnt management system was also found effective at project level. However bottom five and the least effective tools include blogs, the use of intranets, corporate yellow pages and instant messenger at organisational level (Figure 8.4). Peer assist was found less effective.

8.1.2 Impact of KM on design changes

Socialisation at organisational level also had high impact in reducing design changes (Figure 8.1). This includes early involvement of stakeholders and organisations in the supply chain; knowledge creation; and knowledge sharing among project team personnel. Combination at project level involved knowledge capture from project to project. Combination at industry level also had impact on design changes through knowledge dissemination of publications and case studies on best practices. The low impact processes at organisational level include knowledge champions, knowledge identification, and knowledge dissemination through communities of practice (Figure 8.2). At personal level, knowledge transfer ranked low while at project level, knowledge storage ranked low.

Highly efficient tools for reducing design changes were found to be similar to those used for reducing errors and omissions. They are learning reviews, post project reviews, knowledge sharing workshops (Figure 8.3). At project level, lessons learnt management systems were highly effective. The less effective tools include competency management, intranets, blogs and instant messenger (Figure 8.4)

8.1.3 Impact of KM on poor skills

Socialisation at personal level and externalisation at organisational level have the most impact in reducing poor skills (Figure 8.1). While knowledge transfer through mentoring apprenticeships impact poor skills at personal level, knowledge identification and capture of personnel knowledge impact poor skills at organisational level. Knowledge facilitation through knowledge champions also ranks high in this area. The low impact processes are: knowledge creation at organisational level; knowledge storage, knowledge codification from project to document and from project to project (Figure 8.2). KM tools were found to be effective in reducing poor skills. At personal level, peer assist was found very effective (Figure 8.3). At organisational level, post project reviews, competency management, and knowledge sharing workshops were found very effective. At project level, lessons learnt management systems were found very effective however instant messenger, intranets, email, brainstorming and wikis were found less effective in reducing the cost of poor skills.

Figure 8. 1: Impact of KM in reducing COPQ (High-impact KM processes)

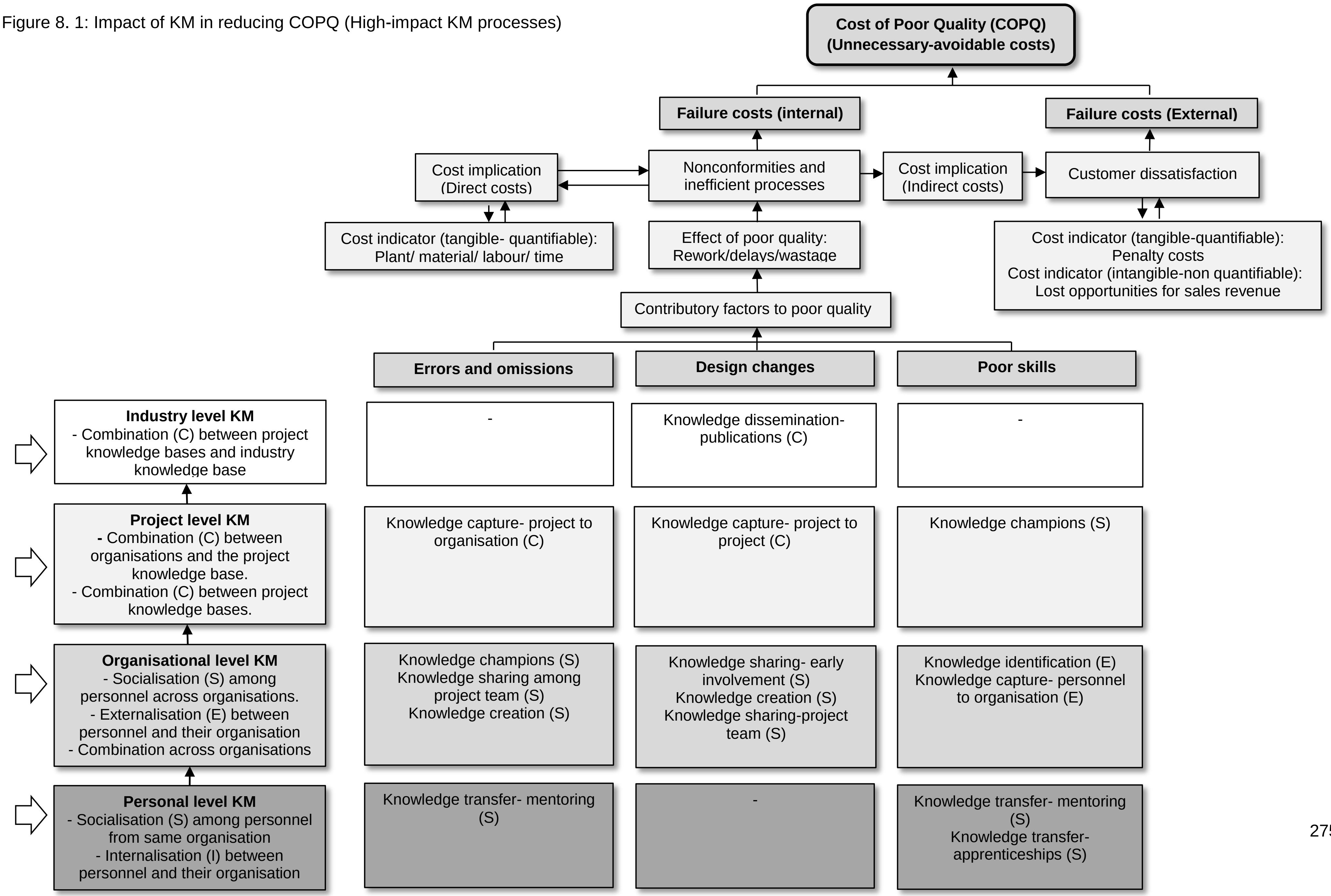


Figure 8. 2: Impact of KM in reducing COPQ (Low-impact KM processes)

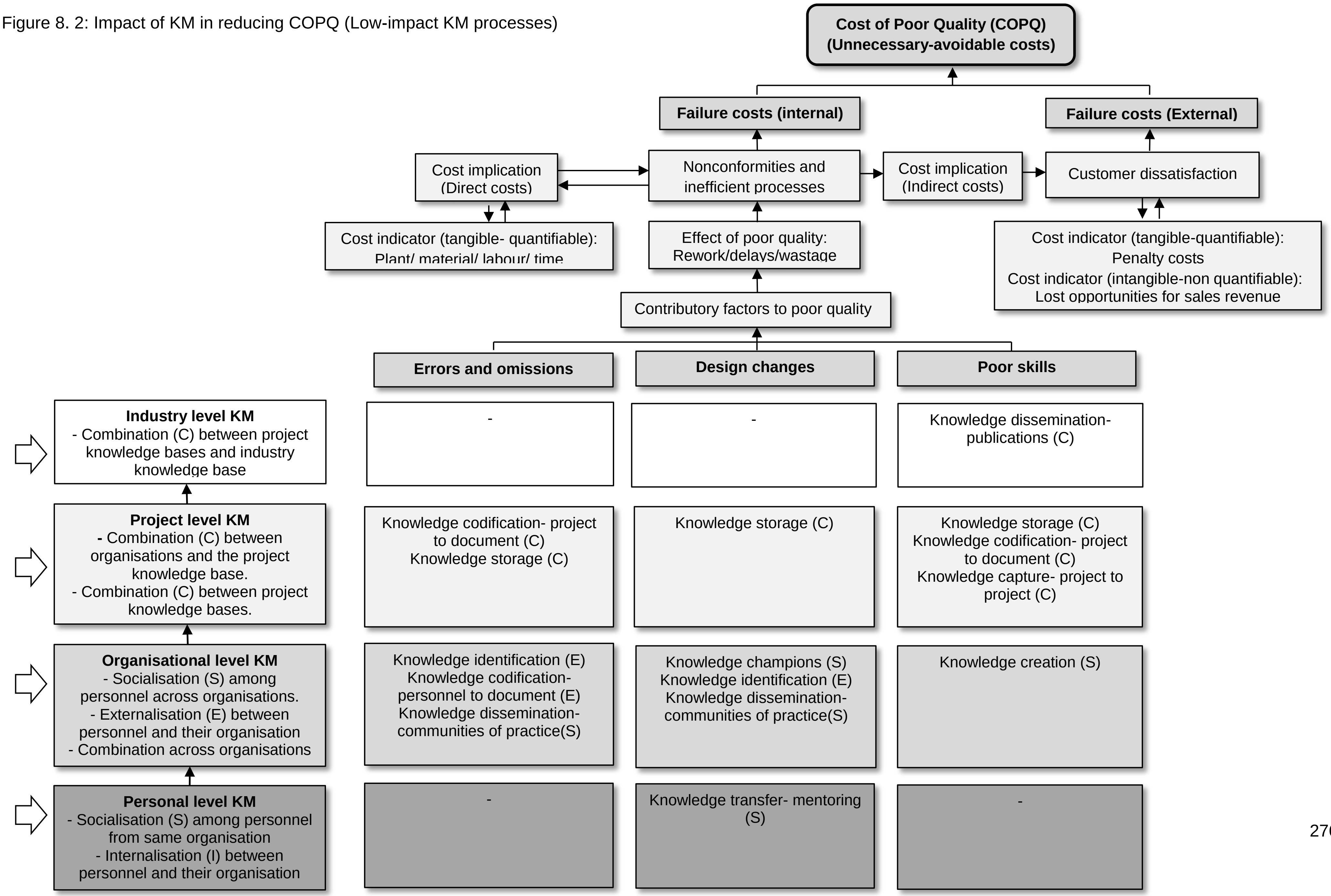


Figure 8. 3: Impact of KM in reducing COPQ (Highly effective KM tools)

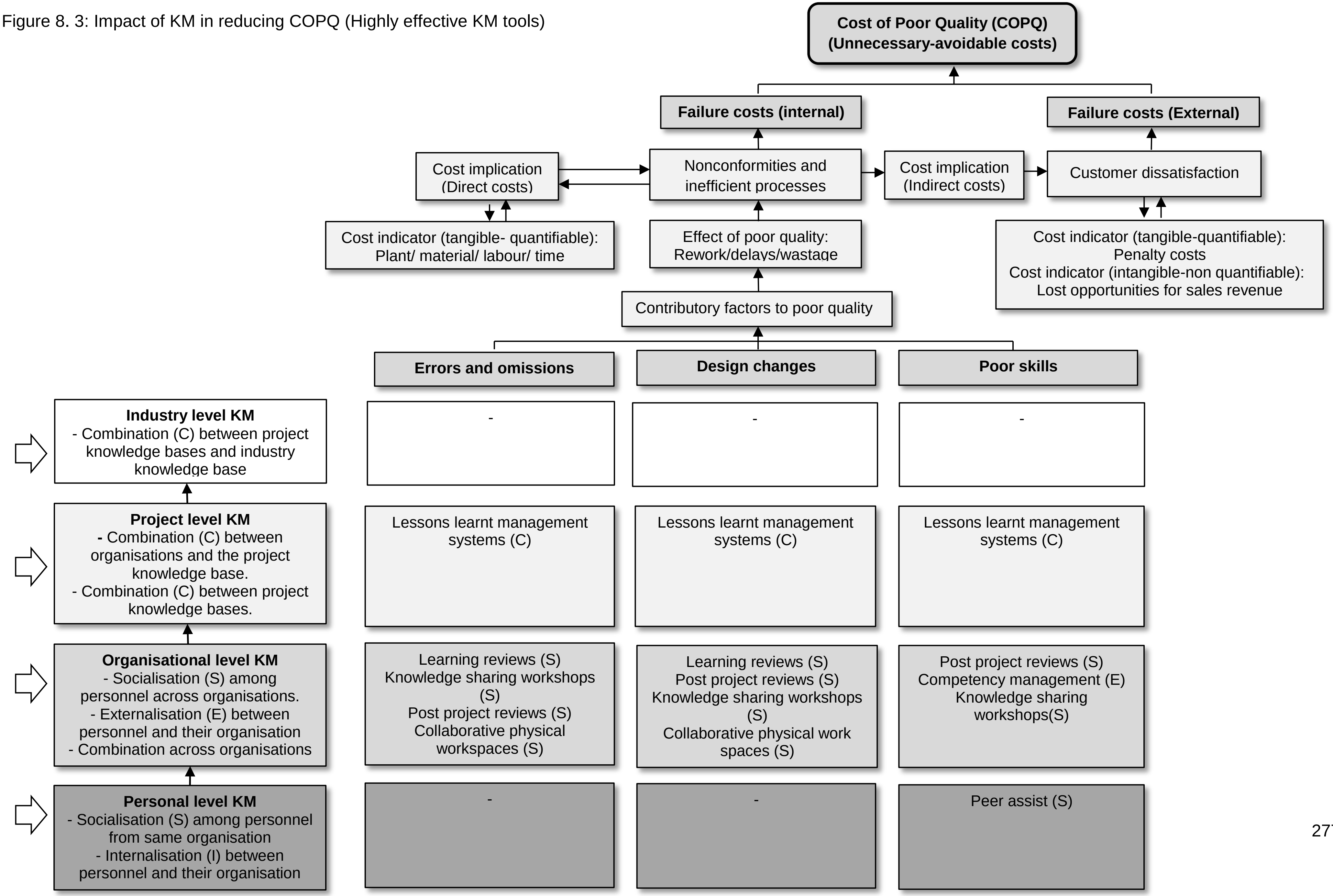
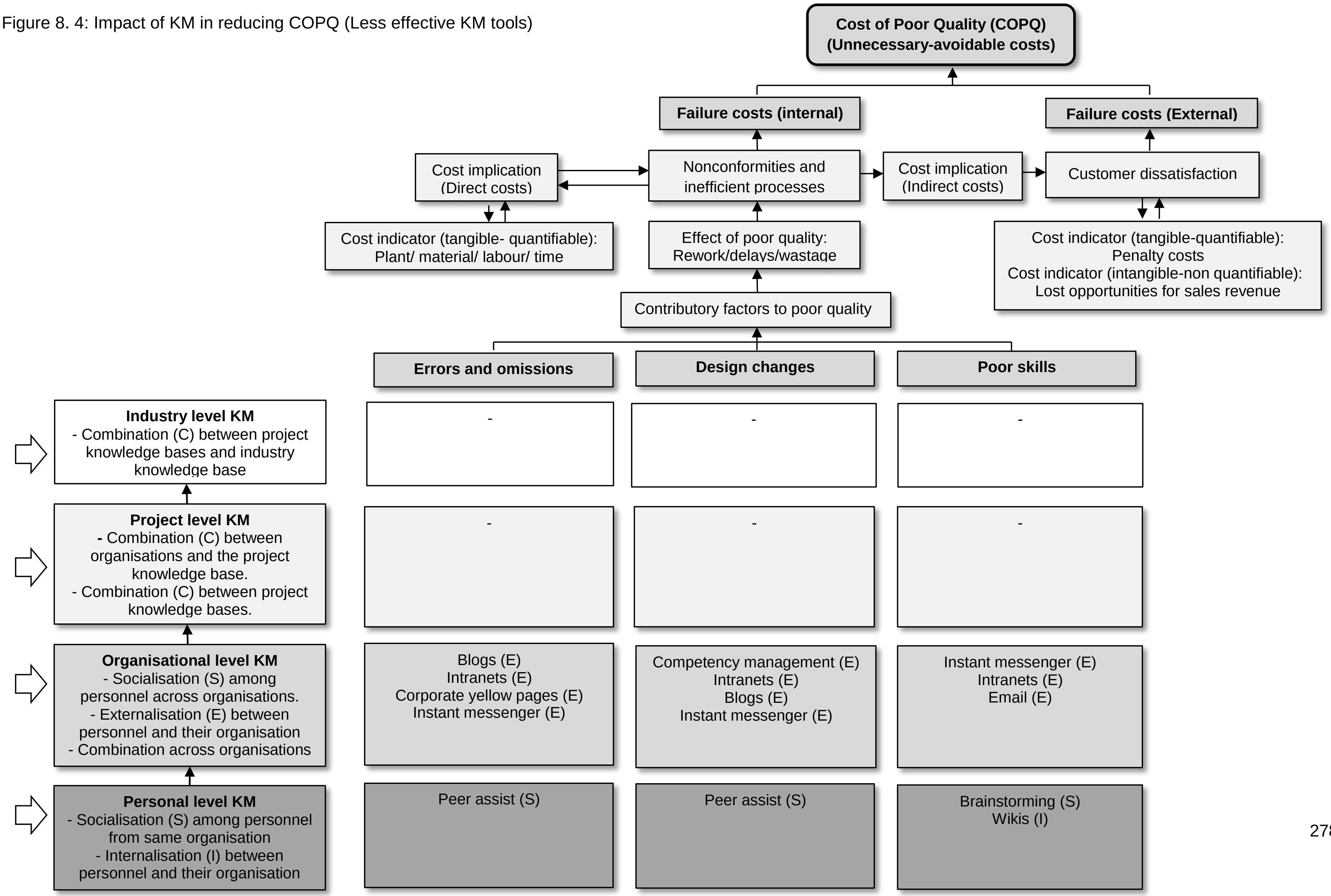


Figure 8. 4: Impact of KM in reducing COPQ (Less effective KM tools)



8.2 KM FRAMEWORK FOR REDUCING COPQ ON CONSTRUCTION PROJECTS

The KM framework for reducing COPQ on construction projects is the final framework resulting from the modification of three previous conceptual frameworks. The first conceptual framework was developed based on the output from literature review to synthesise KM and COPQ concepts and to guide the research in the collection, interpretation and explanation of data. This was presented before the qualitative data collection phase and contained components relating to outputs from literature review, key research questions to be addressed and possible outcomes to be expected. The conceptual framework was modified after the qualitative data collection and analysis. A second framework was presented, the components of which contains the conclusions from the qualitative study and four further questions for the quantitative study. The framework was modified again after the quantitative study data analysis; a third framework was presented which linked the outputs from both qualitative and quantitative studies.

Having synthesised and interpreted the entire data, the final framework is presented in Figure 8.5. The framework is similar to previous framework except that the research questions and hypotheses have been replaced by the findings and conclusions. The framework consists of 5 components labelled from [A] to [E]. Component [A] forms the core of the research and shows the logic between KM and COPQ. The status quo is that COPQ is prevalent and perhaps stems from poor KM. optimising KM therefore is expected to cause a reduction in COPQ.

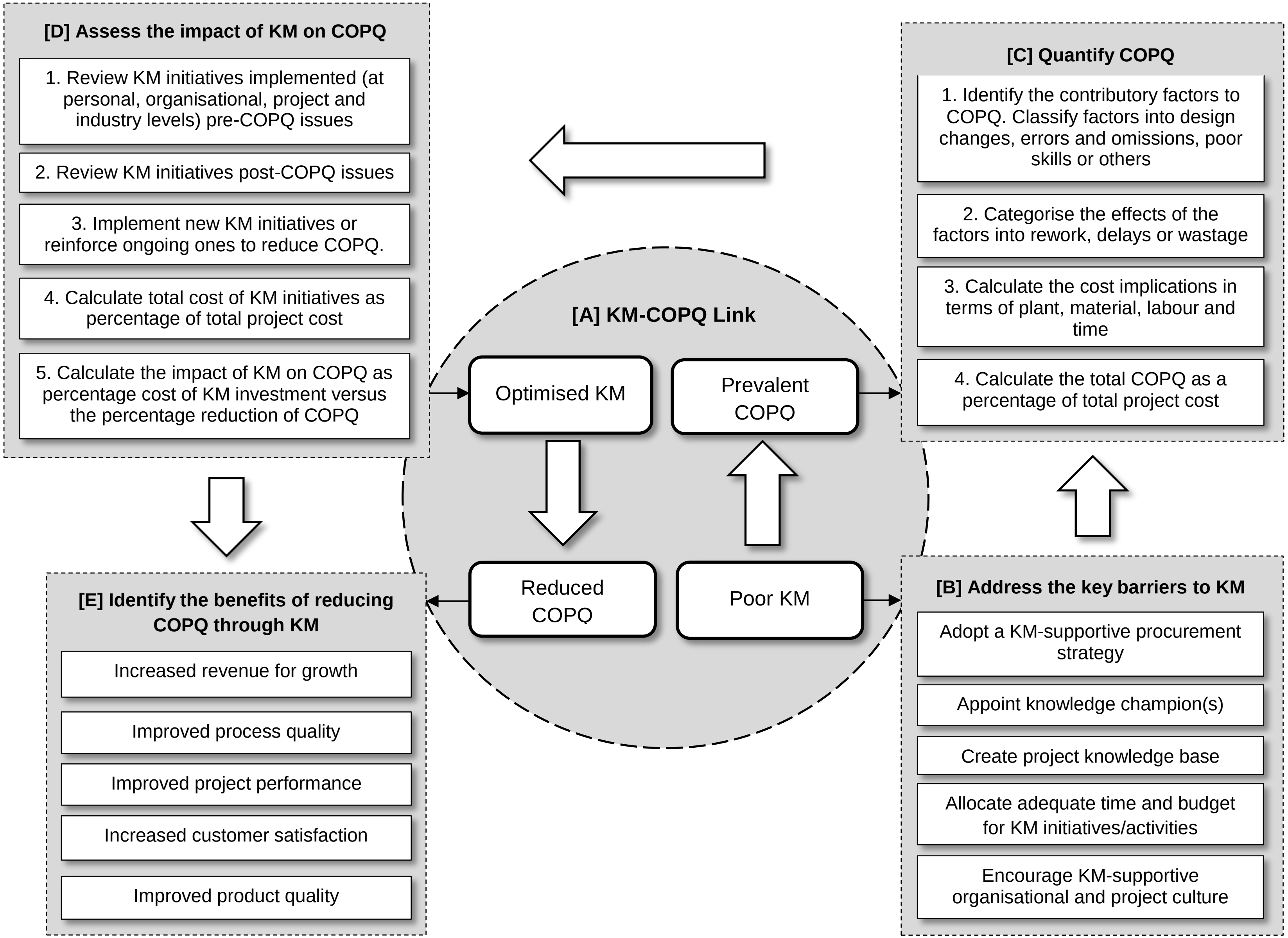


Figure 8. 5: KM framework for reducing COPQ on construction projects

The rationale behind component [A] relates to the two of the main research questions; what is the impact of KM on COPQ? And how can KM be optimised to reduce COPQ? In other words; how does KM currently impact COPQ? And how should KM impact COPQ? The aim of the research therefore is to provide the solution for bridging the gap between poor KM and optimised KM to reduce COPQ.

Component [B] is derived from the qualitative and quantitative data analyses which concluded that in order to optimise KM to reduce COPQ, there are existing key barriers which need to be addressed. Organisations need to therefore adopt a KM-supportive procurement strategy; appoint knowledge champion(s) on every project; create a project knowledge base; allocate adequate time and budget for KM initiatives; and encourage a KM-supportive organisational and project culture.

Component [C] is derived from extensive literature review and qualitative data analysis. An integrated COPQ model was presented in Chapter 3 which showed how all aspects of previous studies of COPQ are interlinked particularly the causes, effects and cost implications of COPQ. One of the conclusions from qualitative data analysis is that organisations do not quantify COPQ neither do they know how to quantify it. A key step to managing COPQ however is the ability to quantify it. The integrated COPQ model therefore was used as a framework for Component [C] to quantify COPQ. A four step approach was adopted as follows: (1) identify the contributory factors to COPQ and classify the factors into design changes, errors and omissions, poor skills and other project-specific classifications (2) categorise the effects of the factors into rework, delays or wastage (3) calculate the cost implications in terms of plant, material, labour, time or penalties (4) calculate the total COPQ as a percentage of total project cost.

Component [D] relates to the assessment of the impact of KM in COPQ and is derived from the critical review of literature and the findings from qualitative and quantitative data. One of the novelty of the research is the categorisation of KM into four levels and the investigation of KM initiatives no the four levels. It was concluded that despite KM initiatives currently in use, it was found that organisations do not assess the impact of KM on COPQ. A five-step approach was therefore presented as follows: (1) review KM initiatives implemented at personal, organisational, project and industry levels before the COPQ issues (2) review KM the initiatives post-COPQ issues (3) implement new KM initiatives or reinforce ongoing initiatives to reduce COPQ (4) calculate total cost of KM initiatives as percentage of total project cost (5) calculate the impact of KM on COPQ as percentage cost of KM investments versus the percentage reduction of COPQ.

Component [E] is derived from literature data collection and analysis. This is the output of the impact of KM on COPQ in which the benefits are categorised as applicable to particular projects. The benefits include increased revenue for growth, improved process quality, improved project performance, increased customer satisfaction and improved product quality. There are so many benefits that can be realised from reducing COPQ through KM, the ones presented in the framework are the ones that ranked highest in the quantitative data analysis.

The framework is a cyclic process which should be repeated periodically e.g. monthly unlike the current practices whereby KM is reviewed at the end of a project phase. This assessment should be conducted regularly especially while the project is still ongoing. This enables knowledge champions or knowledge managers to track repetition of mistakes and lessons learnt. With the use of the framework, no two COPQ issues if any must be the same. Periodical progress report of projects must be produced while the performance on one project can easily be compared with another, using the same methodology.

8.3 EVALUATION OF THE FRAMEWORK

The research adopted a mixed method approach and an exploratory sequential research design. This means that the main aspect of the research is qualitative with a supporting quantitative aspect. In evaluating the KM framework, it is important first to examine the concept validity in research which is described by a wide range of terms. This concept is not a single, fixed or universal, but rather a contingent construct, inescapably grounded in the processes and intentions of particular research methodologies and projects (Winter, 2000).

Although some qualitative researchers have argued that the term validity is not applicable to qualitative research, but at the same time, they have realised the need for some kind of qualifying check or measure for their research. For example, Creswell and Miller (2000) suggest that the validity is affected by the researcher’s perception of validity in the study and the choice of paradigm assumption. As a result, researchers have developed their own concepts of validity and have often generated or adopted what they consider to be the more appropriate terms, such as, quality, rigor and trustworthiness (e.g. Stenbacka, 2001; Davies and Dodd, 2002). The discussion of quality in qualitative research stems from the concerns about validity and reliability in quantitative tradition which involved substituting new term for words such as validity and reliability to reflect interpretivist or qualitative conceptions (Seale, 1999).

According to Stenbacka (2001), the concept of validity should be redefined for qualitative researches. In searching for the meaning of rigor in research, Davies and Dodd (2002) found that the term rigor in research appears in reference to the discussion about reliability and validity. Davies and Dodd (2002) argued that the application of the notion rigor in qualitative research should differ from those in quantitative research by accepting that there is a quantitative bias in the concept of rigor, in which case, one can now move on to develop a re-conception of rigor by exploring subjectivity, reflexivity, and the social interaction of interviewing.

In this research therefore, the term ‘evaluation’ is used rather than ‘validation’. Evaluation is the systematic determination of a subject's merit, worth and significance, using set criteria. Participant evaluation was carried out in which the data and/or findings were returned to participants in order to obtain their evaluation. This involves research participants responding either to forms of initial data, e.g. transcripts of interviews, or observations of activities, in order to check them for accuracy, or to first drafts of interpretive reports to respond, again, to their accuracy, but also to the interpretive claims that are being made (Lincoln and Guba, 1985; Creswell, 2003; Teddlie and Tashakkori, 2009). Mixed methods researchers are increasingly acknowledging the importance of engaging with the views and perspectives of research participants in order to represent these perspectives as fully and validly as possible (Christ 2009, 2010, Mertens et. al. 2010).

The proposed KM framework for reducing COPQ which consolidates much of the research findings were presented to selected industry experts to evaluate based on the following objectives:

- To assess the KM – COPQ link or relationship presented in Component [A] of the framework if the dynamics are truly reflective of situation in practice.
- To confirm that the key barriers identified in Component [B] of the framework are the critical ones to be addressed in the optimisation of KM in reducing COPQ in practice.
- To assess the adequacy and completeness of the four (4) steps to quantifying COPQ presented in Component [C].
- To assess the adequacy and completeness of the five (5) steps to assessing the impact of KM on COPQ presented in Component [D].
- To confirm that the benefits of reducing COPQ through KM presented in Component [E] are consistent with the ones found in practice.
- To assess the dynamics and the interconnectedness of the entire framework.
- To evaluate the usefulness of the framework in driving continuous improvement in the construction industry through the optimisation of KM to reduce COPQ.
- To assess the feasibility of the uptake of the framework and its application in practice.
- To identify how the framework can be improved.

In order to achieve these objectives, interviews were carried out with the selected participants. An evaluation template was developed which contained interview questions that needed to be addressed by the participants (see Appendix 6). The template was developed to ensure consistency in the approach to which the interviews were conducted. Although the interviews were conducted face-to-face, the template served as a guide for the researcher. The template consists of two sections. Section A contains general information about the participants i.e. years of experience in the construction industry, types of construction projects they have undertaken, type of organisations they have worked for, current job designation, job level and area of expertise and so on. Section B contains the evaluation questions stated below:

1. Are the dynamics of the KM – COPQ link reflective of the situation in practice?
2. Are the key barriers identified the critical ones to be addressed in the optimisation of KM in reducing COPQ in practice?
3. Are the four (4) to quantifying COPQ adequate and complete?
4. Are the five (5) steps to assessing the impact of KM on COPQ adequate and complete?
5. Are the benefits of reducing COPQ through KM consistent with the ones found in practice?
6. Are the dynamics and interconnectedness of the framework congruous?
7. Will the framework useful in driving continuous improvement in the construction industry through the optimisation of KM to reduce COPQ?
8. What are your comments on the practicality of the framework; as demonstrated on a spreadsheet?

9. How can the framework be improved?

Five participants were selected for the evaluation of the framework, three of which took part in the semi-structured interviews aspect of the research. Like the semi-structured interviewees, the two new participants for the evaluation were drawn from large construction organisations and have acquired a minimum of 12 years of project and organisational experiences. Regardless of participants' current designation, they have all been involved in KM initiatives in organisations and on projects. Table 8.2 shows the profile of the participants.

Table 8. 2: Profile of participants

Participant ID	Years of experience	Project experience*	Organisation experience*	Current designation
A	33	1, 2, 4, 6	1, 2, 3, 4, 7	Supply chain manager
B	32	1, 6	1, 2, 3, 7	Senior consultant/strategy innovation
C	23	1, 2, 3	1, 2, 3	Director/knowledge management
D	14	4	2, 3, 4, 5	Project engineer
E	12	4	3, 4	Senior design engineer

*Key

Project experience	Organisation experience
1 – Building construction	1 – Client organisation
2 – Highways	2 – Consultancy
3 – Rail	3 – Main contractor
4 – Utility (power)	4 – Design organisation
5 – Utility (water)	5 – Project management
6 – Other	6 – Sub-contractor
	7 – Supplier
	8 – Other

The interviews were conducted individually at their various organisations. The interviews lasted for 2 hours averagely. The researcher first elaborated on the research and the development of the framework to ensure that participants fully understood what was required of them. They were presented with the of the rationale, objectives and outputs of the research through discussions supported by research documents, tables and diagrams to ensure that the participants fully understand the background to the development of the framework. The framework components and dynamics were discussed in details. All the participants are experts in the field of knowledge management particularly within the construction project management context therefore were able to understand and relate to the research.

An Excel spreadsheet version of the framework was also presented to the participants to see how the framework can be practically applied (see Appendix 7). Appendix 8 shows the excerpts from participant responses on the evaluation of the framework. When asked the question about the dynamics of the KM-COPQ link in Element [A] of the framework if it is reflective of the situation in practice, all of the participants agreed that this is reflective of the situation in practice.

> *"Yes definitely, the importance and relevance of knowledge management cannot be overemphasised. We can save tons of money by optimising knowledge management"* – Participant A

> *"I think this is reflective of the situation in practice". I think we struggle a lot in this industry with knowledge management and that's why we haven't been able to make most of it"* – Participant B

When asked about the key barriers identified in Element [B] of the framework, they all agreed to the barriers but with different focus on different areas. While Participant B and Participant D focused on the culture aspect, Participant E focused on the need for knowledge champions.

"Yes especially the culture aspect. At the end of the day it all comes to behaviour. We ought to take knowledge management culture as seriously as we take health and safety" – Participant B

"Yes as far as I can think of, having a knowledge base is good but most importantly an organisational culture in which people willingly push and pull knowledge into and from the knowledge base" – Participant D

"Yes these are the barriers that need to be addressed particularly knowledge champions. We had no knowledge champions on most of the projects I've worked on. This had significant impact on project cost as no one championed lessons learnt from mistakes" – Participant E

When asked about the four (4) steps to quantifying COPQ shown in Element [C] of the framework if adequate and complete, participants agreed to its adequacy and completeness. According the participants, measuring COPQ has always been an issue and having a framework to measure it is beneficial.

"Measuring the cost of poor quality and benchmarking performance has always been a major issue. No one does it so I think the steps are adequate to offer a solution in this area" – Participant A

"We have never quantified the cost of poor quality on projects. But I think the steps can help in quantifying the cost of poor quality" – Participant C

Participants were asked if the five (5) steps to assessing the impact of KM on COPQ shown in [D] are adequate and complete. All the participants agreed to the five steps as complete and adequate for tracking the cost of KM investments versus cost savings due to COPQ reduction. However Participant B noted that it might be a bit complex yet achievable. Participant E suggested the use of KPIs to benchmark the impact.

> *"Though it would appear a bit complex to assess the impact of knowledge management on the cost of poor quality, I would say yes to adequacy of the framework to address this area"* – Participant B

> *"Yes. You may want to include the use of KPIs to benchmark the impact of knowledge management"* – Participant E

Participants were asked if the benefits of reducing COPQ through KM shown in Element [E] of the framework are consistent with the ones found in practice. Although all the participants agreed, Participant B noted the subjectivity of what benefits mean to different organisations.

> *"Yes but is subjective, organisations have different drivers for knowledge management and what sort of benefits they wish to gain from it. Benefits can therefore vary"* – Participant B

All the participants agreed that the dynamics and interconnectedness of the framework are congruous. Four of the participants (A, B, C and E) agreed that the framework would be a useful tool for driving continuous improvement in the industry. Participant C however commented that *"…the industry still has a reputation for doing things the same old ways by repeating mistakes and re-inventing the wheel".* Participant D commented that it depends on the knowledge management technologies available to organisations.

> *"It depends. If we can have a central industry database or knowledge base to store project data, then we can start aggregating data to see if there is continuous improvement"* – Participant D

Participants were asked to comment on the practicality of the framework as demonstrated on a spreadsheet. They all commented that it was practicable and workable as long as organisations make project data available.

> *"It's practical and workable as long as organisations can provide the data required to do the calculations"* – Participant A

Participant C however noted that: *"entering the project data in the spreadsheet could be tedious but the benefits certainly outweighs this"*

When asked how the framework can be improved, Participant A and Participant C commented that this will be known with more tests. The rest of the participants had no comments on how the framework can be improved.

> *"I think we will know in due course after running it with a number of projects"* – Participant A

> *"With more tests come improvement"* – Participant C

Other excerpts from the framework evaluation can be found in Appendix 8. The participants' comments have been useful in achieving the objectives set out for the evaluation of the framework.

8.4 SUMMARY OF CHAPTER 8

This chapter presented an interpretation of the qualitative and quantitative data obtained from the exploratory sequential mixed method research. It connected all aspects of the research including the main research questions, findings and conclusions from both qualitative and quantitative inquiries. It discussed the overall impact of knowledge management on errors and omissions, design changes and poor skills by revisiting the KM-COPQ model matrix presented in previous chapters. It presented the knowledge management framework for reducing the cost of poor quality on construction projects. It also discussed the evaluation of the framework.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a reflective review of the methodological process of the research. It re-states the research aims and objectives. It discusses how the research objectives were achieved. It reviews the research methods and research outputs and their links to the research objectives. It presents the key findings of the research from both theoretical work and fieldwork. It also presents the recommendations, limitations of the research and direction for further work and future studies.

9.1 REFLECTIVE REVIEW OF THE METHODOLOGICAL PROCESS

The aims of the research were stated as follows:

(1) To investigate the impact of knowledge management in reducing the cost of poor quality on construction projects

(2) To develop a knowledge management framework for reducing the cost of poor quality on construction projects.

In order to address the aims, the following research objectives were identified:

(1) To critically review existing literature in the area of KM from both general and construction industry perspectives in order to explore, identify and document the key concepts, processes, tools, KM drivers, enablers, benefits, barriers and issues relating to KM and the possible link to COPQ

(2) To critically review existing literature in the area of quality management with a specific focus on COPQ in construction, in order to explore, identify and document the key concepts of quality, the causes of poor quality, the costs associated with poor quality, the quality management initiatives for reducing COPQ, the issues relating to COPQ in construction and the possible link to KM.

(3) To develop a conceptual framework on the impact of KM in reducing COPQ on construction projects based on the output from literature review, in order to synthesise KM and COPQ concepts and to guide the research in the collection, interpretation and explanation of data.

(4) To collect qualitative and quantitative data from construction organisations across UK in order to investigate the impact of KM in reducing COPQ on construction projects in practice.

(5) To analyse the data from objective 4, comparing the theoretical constructs from objectives 1 – 3 with the analysed data in order to interpret and document the findings, modify the conceptual framework and present a final KM framework for reducing COPQ on construction projects.

(6) To evaluate the proposed framework using selected construction practitioners involved in knowledge management activities.

(7) To summarise the findings, draw final conclusions and recommendations on the impact of KM in reducing COPQ on construction projects.

The research was carried out in three phases (1) theoretical work (2) fieldwork (3) evaluation and conclusion (Figure 9.1). The theoretical work constitutes objectives 1 – 3 of the study and chapters 1 – 5 of the thesis. The fieldwork constitutes objectives 4 and 5 of the study and chapters 6 – 7 of the thesis. The evaluation and conclusion phase covers objectives 6 and 7 of the study and chapters 8 – 9 of the thesis.

9.1.1 How the research objectives were achieved

Objective 1 was achieved through examining the critical points of current body of work in KM through extensive review of literature obtained from multiple sources which included printed journals, online gateways and databases, online journals, reference texts, conference papers and various books in the context of the topic. Past and current literature on the conceptualisations of knowledge and KM were critically reviewed. It was found that KM related not so much on the justification knowledge but on understanding the uses of knowledge in order to effectively deal with tasks that involve knowledge-based activity. This shaped the direction of the study into focusing on the contemporary definitions, concepts and applications of KM.

Knowledge types, sub-types and characteristics were identified. Despite the existence of a plethora of definitions of KM which are daunting and confusing, four commonalities were found: (1) Harnessing and integrating knowledge (2) Adopting a knowledge management process (3) Utilising knowledge management tools, and (4) Aligning knowledge management with organisational strategy. The drivers, enablers, barriers and benefits of knowledge management were identified. The application of KM in construction was examined while a model for applying SECI to the construction supply chain was presented. The issues relating to KM in construction were identified.

Objective 2 was achieved by examining the critical points of current body of work in quality management with particular focus on COPQ through extensive review of literature obtained from multiple sources as those for KM. The existing body of work on quality management was examined with a specific focus on COPQ on construction projects. The conceptualisations of quality including key definitions and applications were examined. Three case studies obtained from a secondary source which deal with construction stakeholders' influence on the definition of quality on construction projects were reviewed and findings presented.

It was found that quality is not just defined by the customer (construction client) but is also influenced by external stakeholders. The causes of poor quality were found to be errors and omissions, design changes and poor skills. COPQ was found to constitute the cost of non-conformities, cost of inefficient processes and the cost of lost opportunity for revenue. It was discovered that the cost of poor quality is endemic and is found to be over 10% of total project costs in certain cases. Quality management initiatives and tools used by organisations in reducing the costs of poor quality were explored. The issues relating to COPQ in construction project management were also identified.

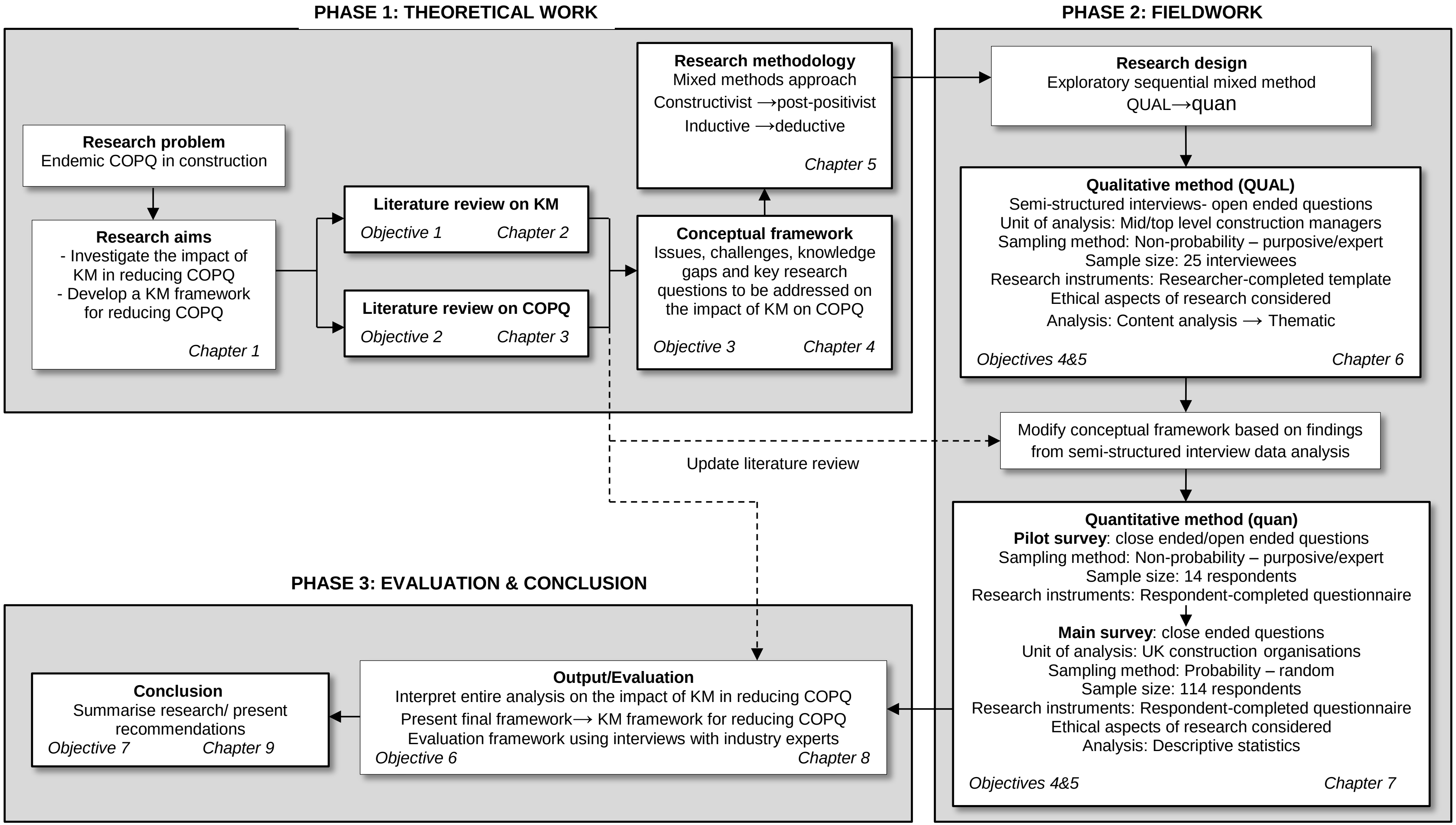


Figure 9. 1: A review of the methodological process for the research

Objective 3 was achieved through the synthesis of the body of work on KM and COPQ. It examined the links between KM and the prevalent COPQ on construction projects. It identified the issues, challenges, knowledge gaps and key research questions on the impact of KM in reducing COPQ. One of the knowledge gaps is that no research has been found to date that has investigated the impact of KM on COPQ in construction. While the COPQ may be regarded as a quality management problem the study takes a different approach of exploring the link between KM and COPQ. This contributes to the novelty of the research.

Key research questions were also presented together with a matrix showing the areas of inquiry. The research questions posed were: (1) what are the contributory factors to the cost of poor quality in practice? (2) What is the impact of knowledge management in reducing the cost of poor quality based on the contributory factors? (3) How can knowledge management be optimised to reduce the cost of poor quality? The conceptual framework was developed based on: the findings from literature on KM and COPQ; issues and challenges relating to KM and COPQ; knowledge gaps; and key research questions to be addressed. The framework was also modified as the research progressed through the data collection and analyses phase.

Objectives 4 and 5 were achieved by utilising mixed methods of data collection and analysis. An exploratory sequential research design was adopted which commenced with qualitative study and was followed up with a quantitative study. The qualitative aspect utilised semi-structured interviews with industry experts as a means of data collection while the quantitative aspect utilised survey questionnaire. Qualitative data was analysed using content analysis while quantitative data was analysed using descriptive and analytical statistics. It was found that KM had positive impact in reducing COPQ but it is uncertain by how much. Quantitative data analysis identified highest ranking and lowest ranking KM processes impacting COPQ. It also identified the highest and lowest ranking KM tools for reducing COPQ. In order to optimise KM, it was found that organisations need to: develop performance metrics to measure or track the impact of KM on COPQ; appoint knowledge champions or knowledge coordinators to facilitate KM; cultivate positive organisational culture towards KM e.g. willingness to readily share knowledge and also pull knowledge from existing knowledge resources within the organisation; allocate appropriate time and budget for KM activities; encourage integration and collaborative working among the supply chain. The conceptual framework was modified as a result of the data analysis from both qualitative and quantitative studies.

Objective 6 was achieved through the interpretation of the entire research data which led to the development of the final framework i.e. KM framework for reducing COPQ on construction projects. The framework was evaluated through participant evaluation by industry experts. KM framework for reducing COPQ on construction projects evaluated.

Objective 7 was achieved by drawing together and documenting all the aspects of the research, including the conclusions and recommendation, in a final report or thesis on the KM framework for reducing COPQ on construction projects. Table 9.1 summarises how the research objectives were achieved through the research methods and outputs.

Table 9. 1: A summary of how the research objectives were achieved

Objectives	Methods	Outputs	Thesis chapters
			1: Introduction to research
1. To critically review existing literature in the area of KM from both general and construction industry perspectives in order to explore, identify and document the key concepts, processes, tools, KM drivers, enablers, benefits, barriers and issues relating to KM and the possible link to COPQ	Examined the critical points of current body of work in KM through extensive review of literature obtained from multiple sources which included printed journals, online gateways and databases, online journals, reference texts, conference papers and various books in the context of the topic. The findings were identified and documented.	• Definition of KM for the study derived from critical review of the work of previous authors. • KM model for the construction supply chain, derived from the integration of the SECI model with the construction supply chain model • Processes, tools, KM drivers, enablers, benefits, barriers and issues relating to KM and the link to COPQ identified and documented.	2: Literature review on knowledge management
2. To critically review existing literature in the area of quality management with a specific focus on COPQ in construction, in order to explore, identify and document the key concepts of quality, the causes of poor quality, the costs associated with poor quality, the quality management initiatives for reducing COPQ, the issues relating to COPQ in construction and the possible link to KM.	Examined the critical points of current body of work in quality management with particular focus on COPQ through extensive review of literature obtained from multiple sources which included printed journals, online gateways and databases, online journals, reference texts, conference papers and various books in the context of the topic. The findings were identified and documented.	• Definition of quality derived from critical review of previous work and secondary data analysis • COPQ model developed from integrating previous models • Key concepts of quality, causes of poor quality, costs associated with poor quality, quality management initiatives for reducing COPQ, issues relating to COPQ in construction and the link to KM identified and documented.	3: Literature review on the cost of poor quality
3. To develop a conceptual framework on the impact of KM in reducing COPQ on construction projects based on the output from literature review, in order to synthesise KM and COPQ concepts and to guide the research in the collection, interpretation and explanation of data.	The conceptual framework was developed based on: the findings from literature on KM and COPQ; issues and challenges relating to KM and COPQ; knowledge gaps; and key research questions to be addressed. The framework was also modified as the research progressed through the data collection and analyses phase.	• Conceptual framework on the impact of KM in reducing COPQ on construction projects developed.	4: Conceptual framework
			5: Research methodology
4. To collect qualitative and quantitative data from construction organisations across UK in order to investigate the impact of KM in reducing COPQ on construction projects in practice. 5. To analyse the data from objective 4, comparing the theoretical constructs from objectives 1 – 3 with the analysed data in order to interpret and document the findings, modify the conceptual framework and present a final KM framework for reducing COPQ on construction projects.	Mixed methods of data collection and analysis was utilised for the research. Exploratory sequential research design was adopted which commenced with qualitative study and was followed up with a quantitative study. The qualitative aspect utilised semi-structured interviews with industry experts as a means of data collection while the quantitative aspect utilised survey questionnaire. Qualitative data was analysed using content analysis while quantitative data was analysed using descriptive and analytical statistics.	• Contributory factors to COPQ identified from qualitative data analysis • Impact of KM on errors and omissions, design changes and poor skills were also identified. • Conceptual framework modified as a result of qualitative data analysis. • Impact of KM processes, efficiencies of KM tools, top barriers and benefits of KM were identified through quantitative data analysis. • Conceptual framework modified as a result of quantitative data analysis.	6: Qualitative study on the impact of knowledge management on the cost of poor quality 7: Quantitative study on the impact of knowledge management on the cost of poor quality
6. To evaluate the proposed framework using selected construction practitioners involved in knowledge management activities.	Framework was evaluated through participant evaluation by industry experts.	• KM framework for reducing COPQ on construction projects evaluated.	8: KM framework for reducing COPQ on construction projects
7. To summarise the findings, draw final conclusions and recommendations on the impact of KM in reducing COPQ on construction projects.	Achieved by drawing together and documenting all the aspects of the research to present a final report/thesis on the KM framework for reducing COPQ on construction projects.	• Research report/thesis presented.	9: Conclusions and recommendations

9.2 KEY FINDINGS

The key findings are two-fold; the first relates to the output from theoretical work while the second relates to the output from field work.

9.2.1 Findings from theoretical work

- KM is invaluable to the construction industry as it is deemed critical for construction organisations to harness and integrate knowledge in order to improve efficiency and increase profitability.
- Despite KM initiatives, construction projects are still plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to additional project costs.
- A major area of focus is on the cost attached to the unnecessary effort of re-doing processes or activities incorrectly implemented the first time often referred to as the cost of poor quality. This includes the cost of errors and omissions, cost of design changes, cost of poor skills and the consequential costs associated with client dissatisfaction
- COPQ is endemic and has been found to range from around 2% to over 10% of total project cost regardless of project type and size
- Previous studies have focused on the constituent aspects of COPQ such as quality failures, non-conformance cost, direct and indirect rework costs, design and construction related change orders. None of the studies have attempted a holistic approach of integrating all these aspects which include design changes, errors and omissions, poor skills which lead to rework, delays and wastage, and quantified in terms of plant, material, labour, time, and penalty costs.

- Previous studies have also adopted different methodologies in quantifying aspects of COPQ, which makes it difficult to compare COPQ from project to project and to benchmark progress in the industry.
- Government reports have criticised the industry for underperforming. Clients are becoming more sophisticated, insisting on better value for money, and demanding more units of construction for fewer units of expenditure. There exists therefore the critical need to formulate strategies for reducing the COPQ in construction.
- Furthermore no research has been found to date that has investigated the impact of KM in reducing COPQ on construction projects.
- The construction industry is project-based thereby posing the challenge of knowledge capture, retention and re-use
- The industry is fragmented thereby brings about the challenge of knowledge integration across organisations
- The industry is criticised for being poor at learning, ‘reinventing the wheel’, repeating mistakes and wasting resources
- Multiple organisations are typically involved in a single project creating the challenge of integration and collaborative working with a focus on the end product and customer value
- Clients are often dissatisfied with project performance, project process and product quality
- There is low profitability of organisations as a result of KM related inefficiencies
- Larger organisations are more likely to formally practice KM than the majority of small organisations

- COPQ is endemic and may be difficult to quantify, especially the intangible aspects of external failure costs.
- There exists a critical need to formulate strategies for reducing COPQ due to government and client demands

9.2.2 Findings from fieldwork

- It was found that projects are still plagued with inefficiencies, repetition of mistakes and lack of lessons learnt thereby contributing to unnecessary cost of re-doing processes incorrectly implemented the first time.
- The constituent elements of COPQ were found to be the cost of errors and omissions, the cost of design changes, and the cost of poor skills.
- Out of the contributory factors to COPQ, 12 were found to contribute to the cost of errors and omissions, 11 to the cost of design changes and 8 to the cost of poor skills.
- There were commonalities found within the contributory factors. Organisational culture was found to be common with errors and omissions, and poor skills. Procurement strategy and poor communication was found to be common with errors and omissions, and design changes. Time constraints and budget constraints were found to contribute to all three constituent elements of COPQ. Considering the commonalties and overlaps, this brings the total contributory factors to twenty four.
- Causal links were found between the COPQ factors contrary to the theoretical suggestion of being mutually exclusive. Errors and omissions for example can be caused by poor skills; errors and omissions on site

can be caused by design issues; design changes can be caused by irreversible errors on site, or by poor skills of the designers. COPQ therefore requires an inclusive and holistic approach to addressing the problem. Nevertheless the findings confirm the prevalent project challenges faced by supply chain organisations in the project context such as time constraints, tight schedules and limited budgets.

- Surprisingly, it was found that COPQ can be profitable to the contractor depending on the procurement strategy or contract type particularly if the contractor was not involved in the design stages of the project. Any form of design changes or rework can therefore benefit the contractor. This can be profitable to the sub-contractors and suppliers as they would have more paid work. COPQ can also be profitable to the designer in the case of client's decision to change the design specification or the scope of work
- KM can be complex and difficult to manage within organisations and on projects. It is even more difficult to assess the impact of KM on COPQ. Overall, KM was found to have positive impact in reducing COPQ however it was found that organisations could not quantify COPQ neither could they measure the extent of the impact of KM on COPQ.
- There was evidence of harnessing and integrating knowledge utilising KM processes (e.g. knowledge sharing and knowledge codification) and tools (e.g. knowledge bases and virtual collaborative workspaces). Other new insights from the findings include the need to develop toolkits to track the impact of KM on COPQ on projects and the need to adopt

procurement strategies that support KM at personal, organisational, project and industry levels.

- It was found that KM currently has not been optimised to reduce COPQ due to a number of barriers. Optimising KM to reduce COPQ involves: developing performance metrics to assess the impact of KM on COPQ on projects; appointing knowledge champions to facilitate KM activities to reduce COPQ; adopting a positive organisational culture towards KM; allocating adequate time for KM activities on projects; allocating adequate budget for KM activities on projects; selecting procurement strategies that support and facilitate KM

9.3 RECOMMENDATIONS

This study makes recommendations for both industry practitioners and academics as follows.

9.3.1 Recommendations for industry practitioners

The recommendations for industry practitioners are closely connected to the findings from the fieldwork phase of this research. This is particularly useful for project managers, knowledge champions, quality managers and continuous improvement managers within the construction supply chain. The study has practical relevance and application in providing construction organisations with the insight that investing in KM and quality management techniques, technologies and systems is important but what is more important is the ability to track the impact of the investment in cost terms. Organisations need to understand and accept that there is an endemic COPQ problem which urgently needs to be addressed. Organisations need to adopt a holistic approach and a robust methodology in quantifying COPQ such as the one presented in this study. Quantifying COPQ forms the basis on which to measure the impact of KM on COPQ. Develop performance metrics to assess the impact of KM on COPQ on projects. Organisations need to appoint leadership in form of knowledge champions to facilitate KM activities to reduce COPQ on projects. Knowledge champions must be adequately supported senior management or project leadership. Senior management need to adopt and encourage a positive organisational and project culture towards KM. Adequate time and budget need to be allocated for KM initiatives and activities. Construction clients need to be aware of the various procurement routes available, hence they need to select procurement routes that facilitate KM especially in the aspects of early involvement, integration and collaborative working of the supply chain. Organisations need to progress beyond personal and organisational level KM to project and industry level KM

9.3.2 Recommendations for academics

The variables generated from this study on KM and COPQ can be useful for academics in extending the current study into other contexts e.g. small and medium size organisations. An exploratory sequential mixed method was adopted for this study, academics may use other approaches to study the same phenomenon. An important recommendation will be to test the KM framework for reducing COPQ on diverse case studies within the construction industry.

9.4 LIMITATIONS OF THE RESEARCH

This research focused on large construction organisations however the UK construction industry is made up of significantly small and medium sized organisations. Some of the findings and recommendations from this study may not be applicable to them. A generic supply chain model for construction project was adopted for this research, however different projects have different supply chain arrangements and procurement strategies. This should therefore be taken into consideration when administering the KM framework for reducing COPQ on specific projects.

9.5 FURTHER WORK AND FUTURE STUDIES

This study focused on multi-projects by investigating the commonalities of KM and COPQ issues regardless of project type. Further work therefore needs to be carried out by identifying project-specific case studies in the industry and piloting the KM framework for reducing COPQ. The case studies will cover various construction industry sectors such as building projects, highways, rail and utility projects. The study also has academic implication as it provides groundwork for further research and extension of study for researchers in the area.

9.6 SUMMARY OF CHAPTER 9

This chapter presented a reflective review of the methodological process of the research. It re-stated the research aims and objectives. It discussed how the research objectives were achieved. It reviewed the research methods and research outputs and their links to the research objectives. It presented the key findings of the research from both theoretical work and fieldwork. It also presented the recommendations, limitations of the research and direction for further work and future studies.

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APPENDICES

Appendix 1: Invitation to participate in a research interview

Invitation to participate in a research interview

Date: ……..……………

Dear …………………………………………………

I am currently carrying out research at the University of Wolverhampton on 'the Impact of Knowledge Management in Reducing the Cost of Poor Quality in Construction' under the supervision of Dr Subashini Suresh and Dr Ezekiel Chinyio.

I would like to invite you to participate in a semi-structured interview relating to the above research based on your years of experience in the industry. The purpose of the interview is to investigate the causes of quality issues in construction and to investigate the impact of knowledge management on these issues. The interview will last for at least 1 hour. Please note that your responses will be treated as highly confidential and transcripts will not contain references to any persons (including yourself) or organisations. Further details about the research and interview are contained in the Information Sheet attached.

Should you be willing to participate, please fill in the attached Consent Form and I will collect it from you on the day of the interview. Please email me your available dates. The summary of results will be available at the conclusion of the academic year. Should you wish to obtain a copy these, please let me know. Thank you very much for your consideration of this invitation. Your participation is highly valued as it will contribute to quality improvement and cost reduction strategies within the construction industry.

I look forward to hearing from you.

Yours Sincerely,

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Appendix 2: Information Sheet for Interview Participants

Information Sheet for Interview Participants

Research Project Title: The Impact of Knowledge Management in Reducing the Cost of Poor Quality in Construction

Project context: The cost of poor quality (COPQ) in construction has been defined as the sum of all costs that will disappear if there are no quality issues in the delivery of a construction project. Quality issues can be classified into: people-related quality issues; process-related quality issues; and product-related quality issues. COPQ have been found to range from 2% to as high as 50% of the contract value. These costs are unnecessary and avoidable. Researchers and practitioners have explored and implemented various cost-cutting and quality improvement strategies yet COPQ is prevalent. Possible reasons may be due to the arguably unique characteristics of construction projects such as the complicated nature of operations, multitude of occupations, professions and organisations, temporary team members, one-off nature of projects, tight schedules and limited budgets. Projects are also people-intensive characterised by a wealth of experiential knowledge. When staff retire or leave projects, they take significant knowledge with them to the detriment of the project delivery. These are knowledge management (KM) issues and challenges which can impact COPQ in diverse ways. A proposed approach to reducing COPQ can therefore be through the optimisation of KM which involves a strategy of 'getting the right knowledge to the right people at the right time'

Definitions

Knowledge Management in this context can be referred to as a strategy of 'getting the right knowledge to the right people at the right time'. This involves managing the interfaces between personal knowledge, organisational knowledge, project knowledge and industry knowledge. Cost of Poor Quality relates to the sum of all costs that would disappear if there were no quality issues and inefficiencies in construction. These include the costs of error, costs of changes, costs of poor skills and the resultant costs associated with customer dissatisfaction.

Purpose of Interview:

- To investigate the contributory factors to the cost of poor quality on construction projects
- To investigate the impact of knowledge management in reducing the cost of poor quality on construction projects
- To identify the barriers to the optimisation of knowledge management in reducing the cost of poor quality on construction projects.

Duration and data storage:

The interview will last for at least 1hour. Please note that interviews will be audio-recorded then transcribed onto a computer system. You may review, edit or erase the transcripts and audio recordings of your interview if you wish to do so. Recordings will then be destroyed. Your responses will be treated as confidential and computer transcripts will not contain references to any persons (including yourself) or organisations. Such references will be replaced by codes known only to me, and all data will be stored securely.

Appendix 3: Consent Form for Participants

THE IMPACT OF KNOWLEDGE MANAGEMENT IN REDUCING THE COST OF POOR QUALITY IN CONSTRUCTION

Consent Statement

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the 'Information Sheet', a copy of which I have retained.
- I understand that I can withdraw from the project at any time and do not have to give a reason for withdrawing.
- I consent to participate in an interview with the researcher.
- I understand that my personal information will remain confidential to the researcher.
- I understand that my organization will not be identified either directly or indirectly.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name: ________________________________

Signature: ___________________________ Date: _________________

Contact Address: ____

Phone Number: ___________________

Email Address: ___________________

Appendix 4: Semi-structured Interview Template

School of Architecture and Built Environment
Faculty of Science and Engineering
University of Wolverhampton

RESEARCH TITLE: THE IMPACT OF KNOWLEDGE MANAGEMENT IN REDUCING THE COST OF POOR QUALITY IN CONSTRUCTION PROJECTS

<u>Semi-structured interview template</u>

Interview ID/No:	
Interviewee ID:	
Interviewee's name:	
Interview date:	
Interview time:	
Interview venue:	
Interview duration:	
Name of interviewee's organisation:	

Section A: General Information

	Question	Response
1.	How many years of construction industry experience do you have?	
2.	Which types of construction projects have you worked on? (E.g. Building? Highways?)	
3.	Which types of organisations have you previously worked for? (E.g. Clients? Contractors?)	
4.	What is your current job designation?	
5.	What is your current job level? (Managerial or operational?)	
6.	What is your area of expertise?	

Section B: Contributory factors to the cost of poor quality on projects

	Question	Response
1.	From your experience of construction projects, what are the contributory factors to the cost of errors and omissions on projects?	
2.	What are the contributory factors to the cost of design changes on projects?	
3.	What are the contributory factors to the cost of poor skills on projects?	

Section C: Impact of knowledge management in reducing the cost of poor quality (based on the identified contributory factors)

	Question	Response
1.	Which knowledge management initiatives were in place on the projects you worked on? How did the initiatives impact the reduction of errors and omissions?	
2.	How did the initiatives impact the reduction of design changes?	
3.	How did the initiatives impact the reduction of poor skills?	

Section D: Optimisation of knowledge management to reduce the cost of poor quality

	Question	Response
1.	From your experience in construction projects and organisations, what are the barriers to knowledge management in reducing the cost of poor quality?	

Appendix 5: Survey questionnaire and cover letter

Dear ______________________________________

I am a PhD researcher at the University of Wolverhampton currently undertaking a study on the Impact of Knowledge Management in Reducing the Cost of Poor Quality on Construction Projects under the supervision of Dr Subashini Suresh and Dr Ezekiel Chinyio. Output from the study is intended to benefit organisations like yours in the areas of cost reduction and quality improvements through the exploitation and optimisation of knowledge management.

A survey questionnaire has been developed as part of the study to explore knowledge management and its impact on the cost of poor quality in construction. I would like to request your help and participation in this important study by spending about 30 minutes to complete the attached questionnaire. The survey is anonymous so as to allow freedom of expression. Your responses will be treated with strict confidentiality. If you have any queries or would like to speak to me, please feel free to contact me on 07947331982. Email: r.olayinka@wlv.ac.uk

Please return completed questionnaire via enclosed freepost envelope. A summary of the survey results can be made available to you at the conclusion of the study. If you wish to obtain a copy of these results, please indicate and also provide your contact details. Thank you for your help and participation.

Yours sincerely,

Raymond Olayinka
PhD Researcher
MI Building
University of Wolverhampton
Wulfruna Street, WV1 1LY

Operational definitions

Knowledge Management (KM): A strategy of 'getting the right knowledge to the right people at the right time'. KM involves managing the interfaces between personal knowledge, organisational knowledge, project knowledge and industry knowledge.

Cost of Poor Quality (COPQ): The sum of all costs that would disappear if there were no quality issues and inefficiencies in construction. These include the costs of error, costs of changes, costs of poor skills and the resultant costs associated with customer dissatisfaction.

Project Organisations: Organisations involved in a construction project such as the client organisation, designers, consultants, main contractor, sub-contractors and suppliers.

Project Team: Project team consists of representatives from the project organisations.

Project Staff: Members of the project team

Performance Metrics: Involves establishing critical processes, identifying specific quantifiable outputs of work, and establishing targets against which results can be scored.

Structure of the questionnaire

The questionnaire is structured into sections shown in the table below:

Section	Description
A	General Information
B	Knowledge Management Activities for Reducing the Cost of Poor Quality on Construction Projects
C	Effectiveness of Knowledge Management Techniques and Technologies in Reducing the Cost of Poor Quality
D	Barriers to Knowledge Management in Reducing the Cost of Poor Quality
E	Benefits of Reducing the Cost of Poor Quality through the Optimisation of Knowledge Management
F	Measurement of the Impact of Knowledge Management on the Cost of Poor Quality
G	Any additional comments

Section A: General Information

How many years of construction industry work experience do you have? Please tick [✓] only one box.

☐ Up to 5years ☐ > 5years up to10 years ☐ >10years up to 15years

☐ >15years up to 20years ☐ > 20years up to 25years ☐ > 25years

What is your current job role? Please tick [✓] only one box.

☐ Civil Engineer ☐ Cost Manager ☐ Architect

☐ Knowledge Manager ☐ Mechanical & Electrical (M&E) ☐ Project Engineer

☐ Project Manager ☐ Quantity Surveyor ☐ Quality Manager

☐ Site Manager ☐ Site Supervisor ☐ Other, please specify ____________________

What is your job level? Please tick [✓] only one box.

☐ Director ☐ Senior Management ☐ Mid-level Management

☐ Junior Management ☐ Operational ☐ Other, please specify ____________________

Please indicate the number of employees in your organisation? Please tick [✓] only one box.

☐ 1-5 ☐ 6-10 ☐ 11-50

☐ 51-250 ☐ 251- 500 ☐ More than 500

What size of projects does your organisation normally undertake? Please tick [✓] only one box.

☐ less than £0.5M ☐ £0.5M- £1M ☐ £1M - £2M

☐ £2M- £10M ☐ More than £10M

Which of the following best describes your organisation? Please tick [✓] only one box.

☐ Client Organisation ☐ Consultancy ☐ Contractor

☐ Designer ☐ Project Management ☐ Sub-contractor

☐ Supplier ☐ Other please specify____________________

Which of the following describes your organisation's area(s) of operation? Please tick [✓] all applicable options.

☐ Building Construction ☐ Highways ☐ Rail

☐ Utility (Power) ☐ Utility (Water) ☐ Other (Please specify) ____________________

What is your level of familiarity with knowledge management? Please tick [✓] only one box.

☐ Low ☐ Moderate ☐ High

What is your level of familiarity with quality management? Please tick [✓] only one box.

☐ Low ☐ Moderate ☐ High

Section B: Knowledge Management Processes for Reducing the Cost of Poor Quality on Construction Projects

The following is a list of **knowledge management processes**; please indicate their level of impact on reducing the aspects of cost of poor quality on construction projects **by ticking the appropriate number.**

Meaning of Scale: **1** = Strong Negative Impact, **2** = Negative Impact, **3** = Positive Impact, **4** = Strong Positive Impact

Knowledge Management Processes	Impact on reducing the cost of **design changes**	Impact on reducing the cost of **construction errors**	Impact on reducing the cost of **poor skills**
Identifying the right knowledge for the right people at the right time	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Capturing the experiential knowledge of staff for organisational use	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Capturing lessons learnt at various stages of the project	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Capturing knowledge from other projects for use on current project	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Converting the experiential knowledge of staff into written documents accessible to other staff	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Converting project knowledge into documents accessible to organisations	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Storing project knowledge in the knowledge bank accessible to staff	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Involving all project stakeholders in the early stages to share knowledge	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Disseminating project knowledge through case study publications	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Disseminating project knowledge through communities of practice	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Sharing of knowledge among project team members	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Creating new knowledge through the collaboration of organisations involved in a project	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Using mentoring programmes to facilitate knowledge transfer among staff	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Using apprenticeship programmes to facilitate knowledge transfer among staff	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Engaging experts to facilitate knowledge management on projects	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**
Assessing the impact of knowledge management on construction activities	**1 2 3 4**	**1 2 3 4**	**1 2 3 4**

Section C: Effectiveness of Knowledge Management Techniques and Technologies in Reducing the Cost of Poor Quality

The following is a list of knowledge management **techniques and technologies**; please indicate their level of effectiveness in reducing the aspects of cost of poor quality on construction projects **by ticking the appropriate number.**

Meaning of scale: **1** = Not at all effective, **2** = Fairly Effective, **3** = Effective, **4** = Very Effective

Knowledge management techniques and technologies	Effectiveness in reducing the cost of **design changes**				Effectiveness in reducing the cost of **construction errors**				Effectiveness in reducing the cost of **poor skills**			
Blogs	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Brainstorming	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Collaborative Physical Workspaces	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Collaborative Virtual Workspaces	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Competence Management	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Corporate Yellow Pages/Expert Locator	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Cross Project Learning	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Email	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Instant Messenger	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Intranets	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Knowledge Bases/Repositories	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Knowledge Cafes	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Knowledge Exchange/Interviews	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Knowledge Sharing Workshops	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Knowledge Mapping	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Learning Histories	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Lessons Learned Management Systems	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Learning Reviews	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Peer Assist	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Post Project Reviews	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Social Networking Services	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Storytelling	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Web Conferencing	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Wikis	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**

Section D: Barriers to Knowledge Management in Reducing the Cost of Poor Quality

The following is a list of **barriers** to knowledge management in reducing the cost of poor quality; from your experience please indicate their level of strength **by ticking the appropriate number.**

<u>Meaning of Scale</u>: 1 = Very Weak Barrier, 2 = Weak Barrier, 3 = Strong Barrier, 4 = Very Strong Barrier

Lack of senior management support	**1**	**2**	**3**	**4**
Adversarial organisational culture	**1**	**2**	**3**	**4**
Complacency of project staff	**1**	**2**	**3**	**4**
Knowledge hoarding	**1**	**2**	**3**	**4**
High staff turnover	**1**	**2**	**3**	**4**
High perceived costs of investing in KM initiatives	**1**	**2**	**3**	**4**
Lack of knowledge managers on projects	**1**	**2**	**3**	**4**
Time constrained nature of projects	**1**	**2**	**3**	**4**
Lack of understanding of KM concepts by project staff	**1**	**2**	**3**	**4**
Lack of collaborative working by project organisations to create new knowledge	**1**	**2**	**3**	**4**
Perception of KM initiatives as 'unnecessary burden'	**1**	**2**	**3**	**4**
Perception of errors as inevitable in construction	**1**	**2**	**3**	**4**
Adversarial contracts detrimental to KM implementation	**1**	**2**	**3**	**4**
Lack of incentives to motivate project staff	**1**	**2**	**3**	**4**
Lack of technological infrastructure to support KM initiatives	**1**	**2**	**3**	**4**
Lack of performance metrics to measure the impact of KM on the cost of poor quality	**1**	**2**	**3**	**4**

Section E: Benefits of Reducing the Cost of Poor Quality through the Optimisation of Knowledge Management

The following is a list of **benefits** of reducing the cost of poor quality through the optimisation of knowledge management; from your experience please indicate your level of agreement **by ticking the appropriate number.**

Meaning of Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

Improved cost efficiency	**1**	**2**	**3**	**4**
Increased customer satisfaction	**1**	**2**	**3**	**4**
Improved project performance	**1**	**2**	**3**	**4**
Increased profitability	**1**	**2**	**3**	**4**
Increased revenue for growth	**1**	**2**	**3**	**4**
Increased competitive advantage	**1**	**2**	**3**	**4**
Improved reputation	**1**	**2**	**3**	**4**
Increased staff motivation	**1**	**2**	**3**	**4**
Improved service quality	**1**	**2**	**3**	**4**
Improved process quality	**1**	**2**	**3**	**4**
Improved product quality	**1**	**2**	**3**	**4**

Section F: Measurement of the Impact of Knowledge Management on the Cost of Poor Quality

The following is a list of questions on the **measurement** of the impact of knowledge management on the cost of poor quality; from your experience please indicate your responses **by ticking the appropriate box.**

	Yes	**No**
Do you currently have a tool to quantify COPQ?		
Do you currently have a tool that measures the impact of KM on COPQ?		
Do you currently have performance metrics to assess the impact of KM on COPQ?		
Would you welcome a new tool for:	**Yes**	**No**
Quantifying COPQ?		
Measuring the impact of KM on COPQ?		
Developing performance metrics for assessing the impact of KM on COPQ?		
Comparing the performances of various projects on the impact of KM on COPQ?		
Measuring the costs and benefits of KM in reducing COPQ?		
Tracking periodical progress of KM in reducing COPQ?		
Assessing the impact of KM on overall project cost?		

Section G: Any additional comments? Please state below:

END OF QUESTIONNAIRE

Thank you very much for your time and input!

Do you want a copy of the key findings? Please tick [✓] only one box. ☐ **Yes** ☐ **No**

If yes provide details:

Name:

Address:

Email:

Appendix 6: Evaluation template

School of Architecture and Built Environment
Faculty of Science and Engineering
University of Wolverhampton

RESEARCH TITLE: A KNOWLEDGE MANAGEMENT FRAMEWORK FOR REDUCING THE COST OF POOR QUALITY ON CONSTRUCTION PROJECTS

<u>Evaluation template</u>

Participant ID:	
Participant's name:	
Date:	
Time:	
Venue:	
Duration:	
Name of Participant's organisation:	

Section A: General Information

	Question	**Response**
1.	How many years of construction industry experience do you have?	
2.	Which types of construction projects have you worked on? (E.g. Building? Highways?)	
3.	Which types of organisations have you previously worked for? (E.g. Clients? Contractors?)	
4.	What is your current job designation?	
5.	What is your current job level? (Managerial or operational?)	
6.	What is your area of expertise?	

Section B: Evaluation of the KM/CoPQ framework

	Question	Response
1.	Are the dynamics of the KM – COPQ link reflective of the situation in practice?	
2.	Are the key barriers identified the critical ones to be addressed in the optimisation of KM in reducing COPQ in practice?	
3.	Are the four (4) to quantifying COPQ adequate and complete?	
4.	Are the five (5) steps to assessing the impact of KM on COPQ adequate and complete?	
5.	Are the benefits of reducing COPQ through KM consistent with the ones found in practice?	
6.	Are the dynamics and interconnectedness of the framework congruous?	
7.	Will the framework useful in driving continuous improvement in the construction industry through the optimisation of KM to reduce COPQ?	
8.	How can the framework be improved?	
9.	What are your comments on the spreadsheet demonstrating the practicality of the framework	

Appendix 7: Excel Spreadsheet format of the KM framework for reducing COPQ

		Cause		Effect			COPQ indicator							
ID	Contributory factors to COPQ	COPQ issue Description	Rework	Delay	Wastage	Plant (£)	Material (£)	Labour (£)	Time (Days)	**KM initiatives pre-CoPQ issues**	**Cost (£)**	**KM initiatives post-CoPQ issues**	**Cost (£)**	**Outcomes**
1	**Errors and omissions**									*e.g. knowledge sharing*		*e.g. lessons learnt system*		
a	Rule-based mistakes	*e.g wrong reinforcement was used*	✔	✔										
b	Knowledge-based mistakes													
c	Slips and lapses of attention													
d	Lack of lessons learnt													
e	Habits													
f	Organisational culture													
g	Time constraints													
h	Budget constraints													
i	Poor communication													
j	Procurement strategy													
k	Design issues													
l	Construction product issues													
m	Others													
Total														
2	**Design changes**													
a	Client/end user change													
b	Other changes													
c	Design change inevitable													
d	Unforseen site conditions													
e	Poor communication													
f	Poor client expertise													
g	Constructability issues													
h	Errors and omissions on site													
i	Procurement strategy													
j	Time constraints													
k	Budget constraints													
l	Others													
Total														
3	**Poor skills**													
a	High personnel turnover													
b	Lack of training													
c	Lack of dedication													
d	Complacency													
e	Time constraints													
f	Budget constraints													
g	Project based nature of industry													
h	Organisational culture													
i	Others													
Total														

Appendix 8: Excerpts from participant responses on the evaluation of the framework

	Question	Participant A	Participant B	Participant C	Participant D	Participant E
1.	Are the dynamics of the KM – COPQ link in [A] reflective of the situation in practice?	*"Yes definitely, the importance and relevance of knowledge management cannot be overemphasised. We can save tons of money by optimising knowledge management"*	*"This is reflective of the situation in practice". I think we struggle a lot in this industry with knowledge management and that's why we haven't been able to make most of it.*	*"Yes they are"*	*"With my experience in knowledge management, I think it is reflective of the construction industry in particular"*	*"Yes"*
2.	Are the key barriers identified in [B] the critical ones to be addressed in the optimisation of KM in reducing COPQ in practice?	*"There is need to actually to benchmark or understand why these problems exist. Yes these barriers are the critical ones to be addressed"*	*"Yes especially the culture aspect. At the end of the day it all comes to behaviour. We ought to take knowledge management culture as seriously as we take health and safety"*	*"A key barrier is time because we are so task focused. We just want to get on and when we finish that project we just want to get on and do the next project. We don't take the time to think about what has gone well what didn't go well. So I'll say lack of time is a critical barrier in addition to others".*	*"Yes as far as I can think of, having a knowledge base is good but most importantly an organisational culture in which people willingly push and pull knowledge into and from the knowledge base".*	*"Yes these are the barriers that need to be addressed particularly knowledge champions. We had no knowledge champions on most of the projects I've worked on. This had significant impact on project cost as no one championed lessons learnt from mistakes"*
3.	Are the four (4) steps to quantifying COPQ shown in [C] adequate and complete?	*"Measuring the cost of poor quality and benchmarking performance has always been a major issue. No one does it so I think the steps are adequate to offer a solution in this area"*	*"Yes they are adequate and complete".*	*"We have never quantified the cost of poor quality on projects. But I think the steps can help in quantifying the cost of poor quality"*	*"I can't say if they are adequate and complete but it is interesting to be able to calculate the total cost of poor quality as a percentage of total project cost. It is a positive step in managing these sorts of cost in construction"*	*"Yes"*
4.	Are the five (5) steps to assessing the impact of KM on COPQ shown in [D] adequate and complete?	*"Yes they are".*	*"Though it would appear a bit complex to assess the impact of knowledge management on the cost of poor quality, I would say yes to adequacy of the framework to address this area".*	*"The sequence is correct, adequate and complete"*	*"Yes"*	*"Yes. You may want to include the use of KPIs to benchmark the impact of knowledge management"*

	Question	Participant A	Participant B	Participant C	Participant D	Participant E
5.	Are the benefits of reducing COPQ through KM shown in [E] consistent with the ones found in practice?	*"Yes definitely the cost of poor quality will reduce if knowledge management is properly implemented"*	*"Yes but is subjective, organisations have different drivers for knowledge management and what sort of benefits they wish to gain from it. Benefits can therefore vary".*	*"Yes. Profitability is currently low in the industry. Organisations can increase their revenues if poor quality is reduced".*	*"Yes"*	*"Yes"*
6.	Are the dynamics and interconnectedness of the framework congruous?	*"Yes definitely"*	*"Yes they seem in agreement"*	*"Yes they connect well"*	*"Yes it follows a logical flow"*	*"Yes".*
7.	Will the framework be useful in driving continuous improvement in the construction industry?	*"Yes it should be useful to drive continuous improvement if implemented on multiple projects"*	*"Yes it can be useful in this area"*	*"Yes, although the industry still has a reputation for doing things the same old ways by repeating mistakes and re-inventing the wheel".*	*"It depends. If we can have a central industry database or knowledge base to store project data, then we can start aggregating data to see if there is continuous improvement".*	*"Yes. Perhaps some form of KPIs is needed here"*
8.	What are your comments on the practicality of the framework; as demonstrated on a spreadsheet?	*"It's practical and workable as long as organisations can provide the data required to do the calculations"*	*"It's great. Senior managers will be interested to see the impact of knowledge management in figures. If you can't measure you can't manage. This will aid decision-making processes"*	*"Entering the project data in the spreadsheet could be tedious but the benefits certainly outweighs this"*	*"It is practical as long as data is readily available"*	*"It is practical and usable"*
9.	How can the framework be improved?	*"I think we will know in due course after running it with a number of projects"*	*"No comments on this at the moment"*	*"With more tests come improvement"*	*"I can't say at the moment"*	*"No comments"*